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MODIFIED HELICOPTER ICING SPRAY SYSTEM EVALUATION.(U)
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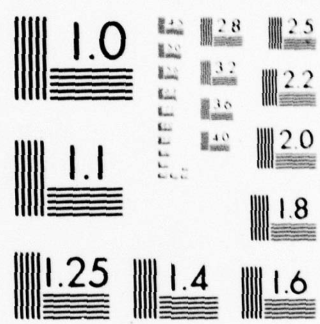

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MODIFIED HELICOPTER ICING SPRAY SYSTEM EVALUATION

FINAL REPORT

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UNITED STATES ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
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The United States Army Aviation Engineering Flight Activity conducted qualification tests of a modified helicopter icing spray system installed on a CH-47C helicopter. The initial tests were conducted at Edwards Air Force Base, California, between 23 September and 4 December 1975. Following a further modification to the icing spray system, six additional flights were conducted between 15 and 30 June 1976. All tests required 55 flight hours (41 flights).

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20. Abstract

During the first testing period, structural and dynamic tests were conducted throughout the CH-47C flight envelope and the physical properties of the spray cloud generated by the modified icing spray system were measured. Two deficiencies were found: boom stresses greater than the materials endurance limit which severely restricted the maximum airspeed at which the system could be operated (110 knots true airspeed), and an inadequate and unsafe boom extension/retraction system. Additional modification was made to the system and envelope expansion tests were repeated. During the second testing period, the two deficiencies were eliminated. However, flight with the boom retracted (except at very low airspeeds) and flight at a rotor speed of 235 rpm continued to produce excessive boom stresses. These excessive stresses constituted a shortcoming. Additional modification to the HISS was made to correct this shortcoming. The modified HISS with this additional change is airworthy within the unrestricted CH-47C flight envelope.

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INTRODUCTION

BACKGROUND

1. The United States Army Aviation Engineering Flight Activity (USAAEFA) conducted qualification tests in 1973 of a helicopter icing spray system (HISS) mounted on a CH-47C helicopter (ref 1, app A). This system was subsequently used during simulated icing tests of several Army helicopters. During these tests several deficiencies of the HISS were noted. The most significant deficiencies were (1) insufficient depth of the spray cloud; (2) rotor downwash and vortices from the CH-47C in the spray cloud, making it extremely difficult to stabilize a test aircraft in the spray cloud at a constant distance from the HISS; (3) nonuniformity of the liquid water content (LWC) in the spray cloud; and (4) corrosion in the water lines. The All American Engineering Company (AAE), which designed and built the HISS, was contracted to modify the system to correct the deficiencies and shortcomings noted in the Army tests. The United States Army Aviation Systems Command (AVSCOM) requested USAAEFA to conduct qualification tests of the modified HISS (ref 2). Results of a follow-on test of the HISS, which was conducted to qualify improvements made by All American Engineering (AAE) subsequent to this evaluation, are included in Appendix F.

TEST OBJECTIVES

2. The objectives of this evaluation were as follows:

a. To conduct an airworthiness evaluation of the modified HISS installed on a CH-47C aircraft.

b. To determine if the modified HISS meets the requirements of the development contract (ref 3, app A).

c. To evaluate the suitability of the modified HISS in simulating an icing environment in which to flight test aircraft.

DESCRIPTION

3. The modified HISS (fig. A) consists of two horizontal booms with spray nozzles and atomizers, internal and external supporting structure for these booms, hydraulic actuators to extend and retract the external apparatus, an 1800-gallon unpressurized

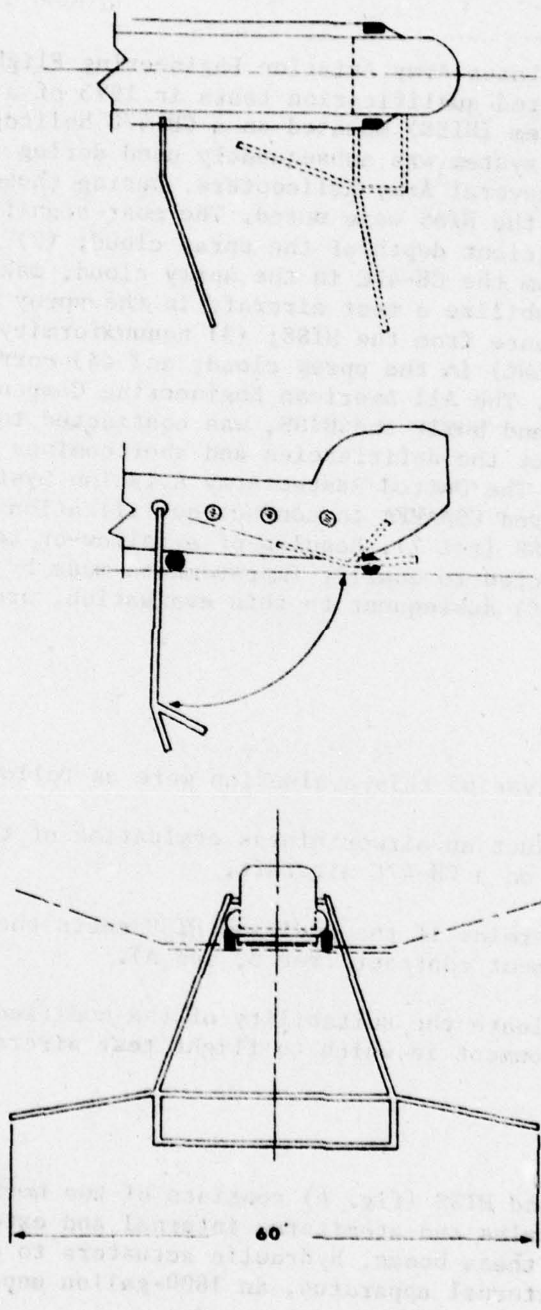


Figure A. Dual Boom Configuration.

water tank, and operator control equipment. In the extended position the upper and lower horizontal booms are 20 and 25 feet below the aircraft, respectively. The upper horizontal boom and vertical extensions are made of steel. The lower horizontal boom and vertical extensions are made of aluminum. The booms and part of the supporting structure are jettisonable in an emergency. The water can also be jettisoned.

4. The spray cloud is created by pumping water from the tank to the nozzles in the booms and atomizing the water with pressurized air from the aircraft engine compressor section. The LWC and water droplet size distribution are controlled by adjusting the water flow rate and the air pressure. There are 174 nozzle locations on the booms. Atomizers can be used at only 54 of the locations at one time because of a limited air supply. Nozzle spacing on the two booms is shown in figure B. A complete description of the icing spray system may be found in the AAE handbook (ref 4, app A). A complete description of the CH-47C helicopter is contained in the operator's manual (ref 5).

5. Because of problems with the initial dual boom system, the extension/retraction system was modified and a stiffener was added to the lower horizontal spray boom. The configuration of the stiffener is shown in figure C.

TEST SCOPE

6. The initial modified HISS qualification tests were conducted by USAAEFA at Edwards Air Force Base, California, between 23 September and 4 December 1975. Following a further modification to the HISS, 6 additional flights were conducted between 15 and 30 June 1976. All tests required 55 flight hours (41 flights). Maintenance and instrumentation support were provided by USAAEFA. The spray equipment was installed by AAE with the assistance of USAAEFA personnel. The limitations of the safety-of-flight releases (refs 6 and 7, app A) were observed throughout these tests.

7. The inital tests were conducted in two phases: envelope expansion and spray cloud measurements. Maximum airspeed during both phases was limited by oscillatory stresses in the lower horizontal boom. The system was subsequently modified to correct this and other problems, and envelope expansion tests were conducted on the modified system. The test conditions for the first envelope expansion, the spray cloud measurement, and the second envelope expansion tests are shown in tables 1, 2, and 3, respectively.

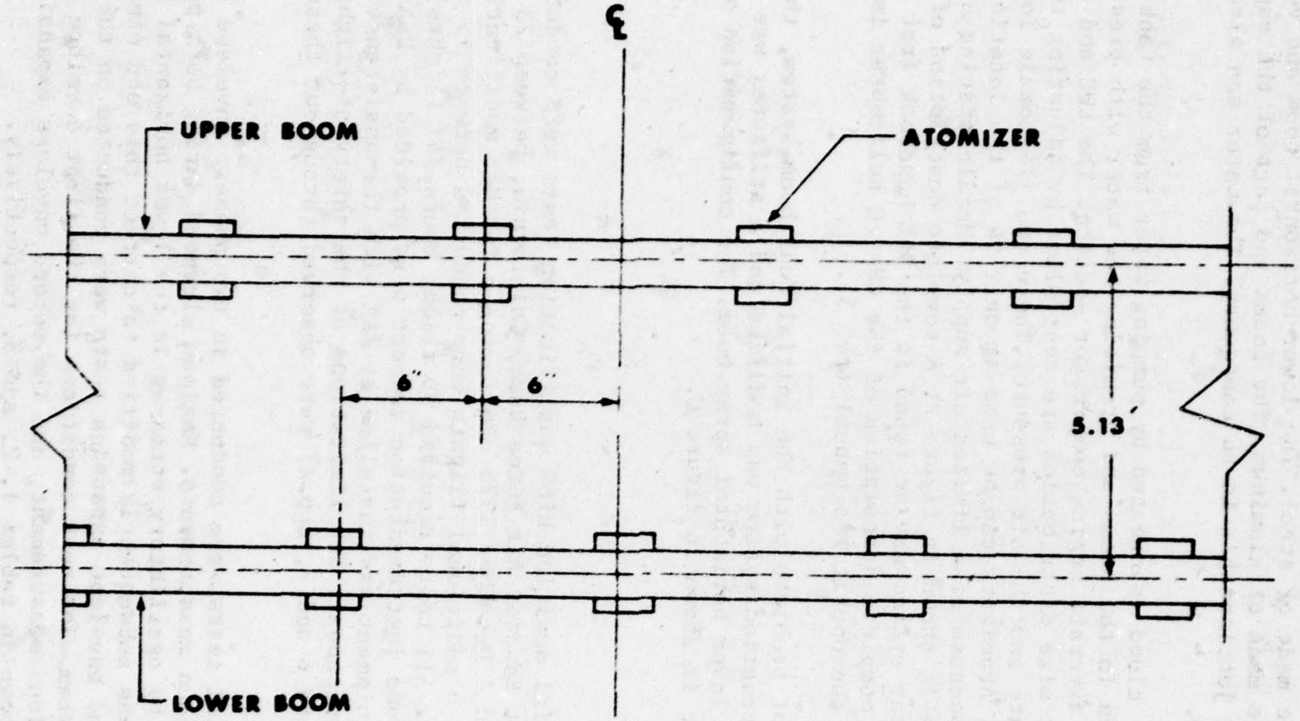


Figure B. Atomizer Arrangement Dual Booms.

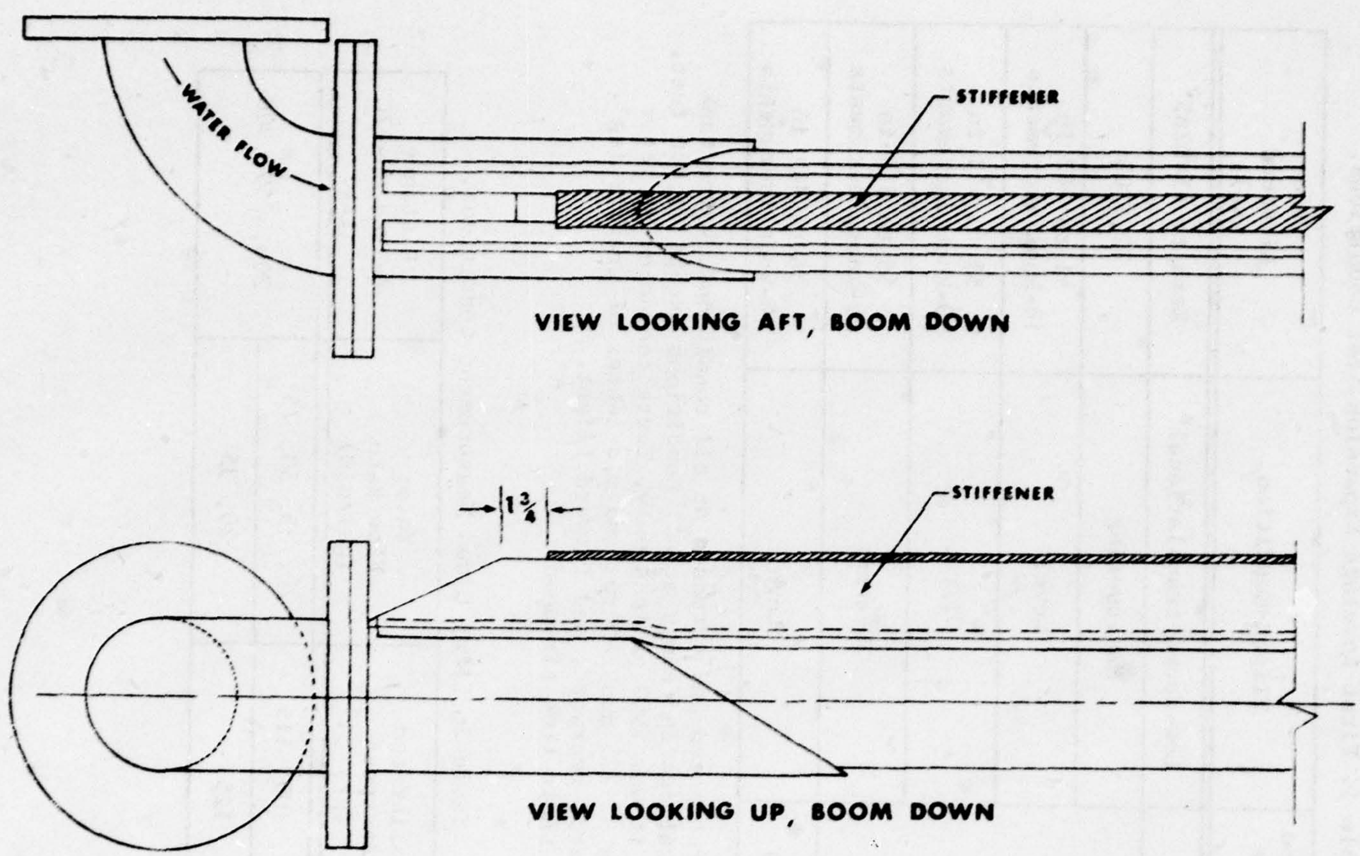


Figure C. Stiffener Configuration.

Table 1. First Envelope Expansion Test Conditions.[1]

Calibrated Altitude (ft)	Flight Condition	True Airspeed (kt)
2800	Low-speed translational[2]	Zero to 45 KTAS[3]
7160	Maneuvering	72, 103
	Level	51 to 142 in 10-knot increments
	Climb	55 to 111 in 10-knot increments
	Descent	55 to 116 in 10-knot increments
11,800	Level	56 to 141 in 10-knot increments

[1]Boom retracted and extended at all conditions. Water tank 1500 gallons and empty at all conditions except 11,800 feet, where it was 1500 gallons only. Tests conducted at rotor speeds of 235 and 245 rpm and mid center of gravity (cg).
[2]Sideward, rearward, and forward flight.
[3]KTAS: Knots true airspeed.

Table 2. Spray Cloud Measurement Conditions.

Calibrated Airspeed (kt)	Water Flow Rate (gal/min)	Distance Behind CH-47C (ft)
85, 100, 115	20, 35, 50, 75	200, 250, 300
125	20, 35	

Table 3. Second Envelope Expansion Test Conditions.[1]

Test	Density Altitude (ft)	Flight Condition	True Airspeed (kt)	Boom Position	Rotor Speed (rpm)
Expansion	4000 OGE[2]	Low-speed translational[3]	Zero to 50 KTAS	Retracted	245
Expansion	9800	Level	65 to 142 in 10-knot increments	Extended and retracted	235, 245
Spray	9800	Level	65 to 142 in 10-knot increments	Extended	245

[1]1500 gallons water, stiffener installed on lower horizontal boom, mid cg.
[2]OGE: Out of ground effect.
[3]Sideward, rearward, and forward flight.

TEST METHODOLOGY

8. Since flight envelope expansion was inherent in the modified HISS qualification tests, these tests were conducted in accordance with the provisions of AVSCOM Regulation No. 70-11 (ref 8, app A). The engineering analysis required by the regulation consisted of technical reviews of AAE reports by AVSCOM prior to issuing a safety-of-flight release, as well as an independent analysis of spray boom dynamics by the Ames Directorate of the United States Army Air Mobility Research and Development Laboratory (ref 9) and an independent AVSCOM structural analysis. The USAAEFA technical committee also reviewed these documents and the test operations plan for the project (ref 10). The test aircraft and spray system were instrumented as described in appendix B. Data were monitored in real time by telemetry during all envelope expansion and cloud measurement flights. Detailed methods of test are outlined in the appropriate sections of the Results and Discussion section of this report.

RESULTS AND DISCUSSION

GENERAL

9. Qualification tests of a modified HISS installed on a CH-47C helicopter were conducted to determine the airworthiness of the system and to evaluate the system's capability to simulate a natural icing environment in which to flight test helicopters. First, structural and dynamic tests were conducted throughout the CH-47C flight envelope and then the physical properties of the spray cloud generated by the modified HISS were measured. Two deficiencies of the modified HISS were found: boom stresses greater than the materials endurance limit which severely restricted the maximum airspeed of the CH-47C/HISS (110 KTAS), and an inadequate and unsafe boom extension/retraction system. Additional modification was made to the system and envelope expansion tests were repeated. During the second envelope expansion tests, the two deficiencies were eliminated. However, flight with the boom retracted (except at very low airspeeds) and flight at a rotor speed of 235 rpm produced excessive boom stresses. Attempts to relate the measured LWC of the spray cloud to water flow rate, relative humidity, cloud geometry, distance behind the CH-47C, or CH-47C airspeed were unsuccessful

FLIGHT ENVELOPE EXPANSION

General

10. The initial flight envelope expansion tests were conducted in three flight regimes: low-speed translational flight; forward climbing, level, and descending flight; and maneuvering flight. At each stabilized flight condition, aircraft control margins, boom stresses, and boom dynamic response were measured. Maximum airspeed of the CH-47C/HISS was limited by lower horizontal boom oscillatory stresses during the initial envelope expansion tests. Following installation of the stiffener to the lower boom, maximum airspeed was restricted by aircraft power available with the boom down at a rotor speed of 245 rpm. At 235 rpm, or with the boom retracted, boom oscillatory stresses were excessive.

Weight and Balance

11. Prior to testing, the aircraft gross weight and longitudinal cg were determined. The aircraft was weighed with the boom stowed and instrumentation installed at the following conditions:

a. No fuel, no water.

b. No fuel, 1100 gallons of water.

c. Full main and forward auxiliary fuel tanks, 1100 gallons of water (two weighings).

d. Full main and forward auxiliary fuel tanks, 1500 gallons of water.

e. Full main and forward auxiliary fuel tanks, no water.

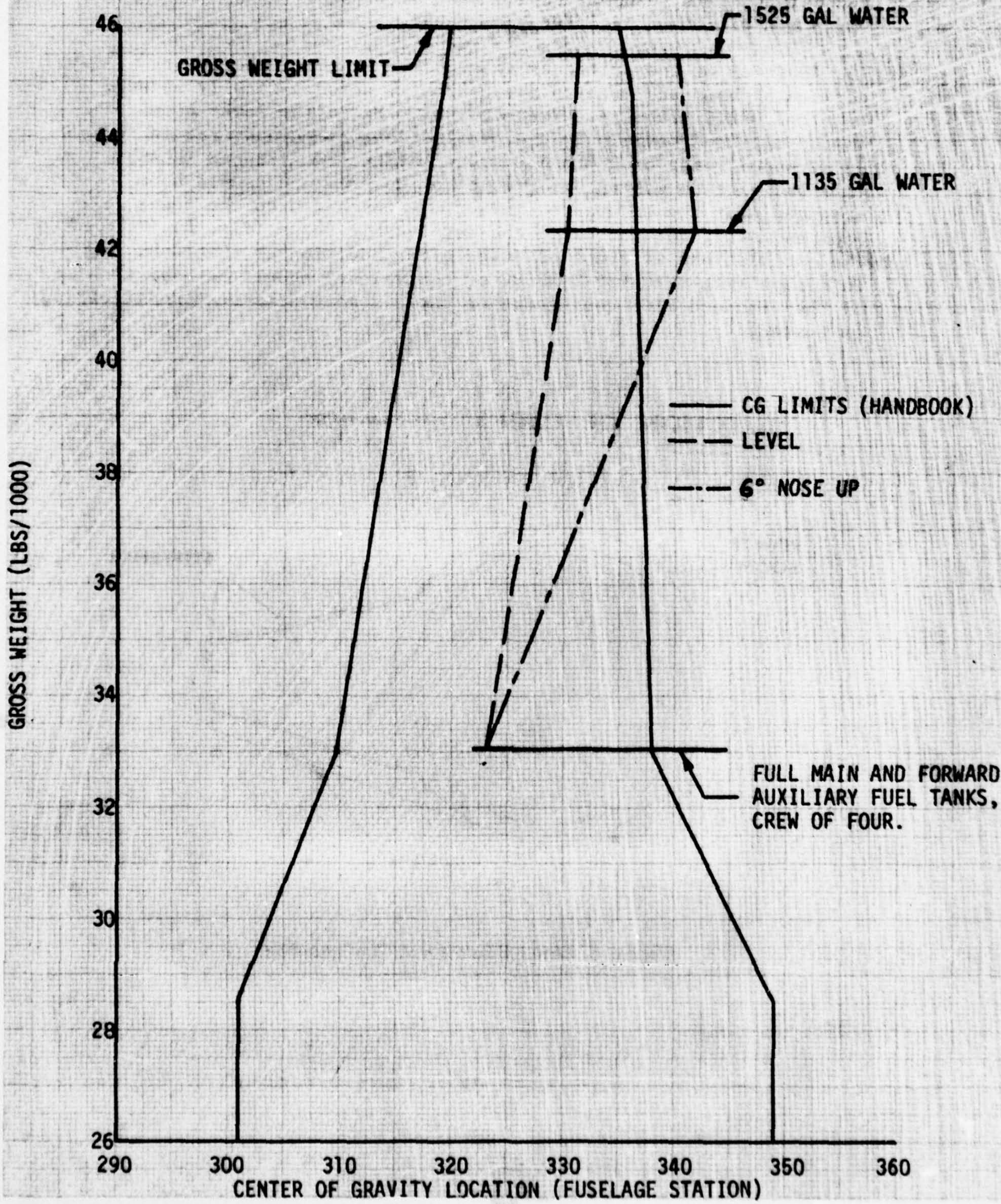
12. All of the above weighings were completed at a level aircraft attitude except for one weighing at each of configurations c and d, where a 6-degree nose-up attitude weighing was performed to determine aircraft cg change caused by water shifting to the aft of a partially filled water tank. As shown by figure D, the water transfer resulted in an aircraft cg shift of approximately 10 inches, which moved the cg beyond the operator's manual aft limit. This condition was cleared for flight by the safety-of-flight release.

13. The test plan required weighing in configurations c and d to be at a 7-degree nose-up attitude (the lift-off attitude of the CH-47C/HISS). However, a 7-degree attitude could not be achieved because the lower boom contacted the ground at a 6-degree nose-up attitude. Therefore, the lower vertical extension tubes were canted 6 degrees to provide adequate ground clearance during lift-off to a hover. This modification was accomplished prior to the start of flight tests.

<u>Boom Dynamics</u>

14. Boom dynamic response to gusts was evaluated at each stabilized test condition shown in table 1 by making 1-inch, 1/2-second pulse control inputs about each axis. Response to lateral and directional control pulses was well damped at all conditions tested. Boom response to longitudinal inputs was a symmetrical pendulum-type oscillation at a frequency of approximately 0.8 hertz (Hz). The damping of this oscillation decreased with airspeed from a damping ratio of 0.057 at 107 KTAS to 0.043 at 145 KTAS. Although the damping of this dynamic mode was low, the damping was greater than that of the low-frequency modes of the previous HISS boom configuration. The oscillation could be felt in the aircraft during flight in turbulence but presented no aircraft control or boom stress problems. Response to gusts was again checked with the stiffener installed and found unchanged. Dynamic response of the boom system to simulated gusts was satisfactory.

FIGURE D
CH-47C CENTER OF GRAVITY SUMMARY
BOOM RETRACTED



The lower (aluminum) horizontal boom did respond to the aircraft 1-per-rotor-revolution (1/rev) and 3/rev excitation under some conditions. This response caused some structural fatigue problems which are discussed in later paragraphs.

15. Addition of the stiffener changed the shape of the lower horizontal boom and created an apparently aerodynamically induced vertical oscillation at a frequency of 6 Hz in the lower boom in the extended position. This oscillation was encountered in an airspeed range of 90 to 110 knots calibrated airspeed (KCAS). This oscillation was uncomfortable to the crew and caused boom stresses near the endurance limit. Tape was added to the lower boom and stiffener to change the aerodynamic shape (fig. E). The oscillations were not observed after addition of the tape. This tape (MIL-SPEC-PPP-T-0060C or equivalent) should be a part of the standard HISS configuration until a more permanent modification is tested.

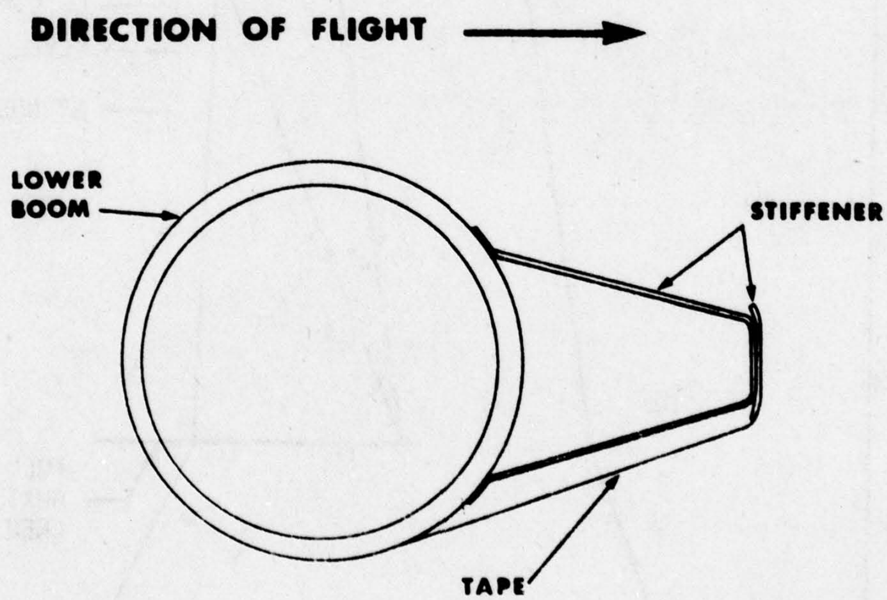


Figure E. Lower Boom Final Configuration.

Boom Stresses

16. Boom stresses at the locations shown in appendix B were recorded at the flight conditions presented in tables 1 and 3. The tests were conducted in smooth air with control motion held to a minimum. Therefore, the stresses presented are the minimum encountered at the test conditions. The data are presented as mean bending stress (vector sum of the bending in two axes) and alternating stress (one-half peak-to-peak stress in each axis). Stress data gathered in level, climbing, descending, and maneuvering flight prior to stiffener installation are presented in figures 1 through 18, appendix C. Stress data at the critical location, gathered after stiffener installation, are presented in figures 19 through 22. Strain gage locations are shown in figure 1, appendix B. Predicted maximum stress levels at all strain gage locations are given in AAE Report P-281 (ref 11, app A).

17. The alternating stresses in the steel components of the boom system were well below allowable fatigue limits at all conditions tested. Mean stresses in steel components were well below the design limit stresses specified in the safety-of-flight release except for bending at location D on the outrigger. Mean bending stress at this location exceeded the design limit at high speed. However, the stresses were well below yield strength for the steel used in the outrigger. Addition of the stiffener had no effect on the stresses in steel components. Stresses in steel members of the boom system are acceptable.

18. The lower horizontal spray boom, vertical tubes, and 90-degree elbows were made of heat-treated aluminum alloy. After fabrication, the welded areas were not heat-treated, and therefore, material strength near welds was less than the strength of heat-treated alloy. Allowable stresses for the two types of material are shown in figure F. After completion of the low-speed translational flights during the first envelope expansion tests (5.9 hours of flight), fatigue failures were found near welds on both the vertical tubes (app D). Subsequently, AAE built new, stronger vertical tubes and heat-treated the tubes and 90-degree elbows after welding. The horizontal boom was left in the "as welded" condition. The new tubes were used for the remainder of the tests and no failures were encountered.

19. Throughout the level flight tests, before stiffener installation, high 1/rev and 3/rev oscillations were present in the aluminum sections of the spray boom system. With the boom UP, the oscillations were vertical and with the boom DOWN, they were fore/aft. The magnitude of the oscillations generally increased as aircraft vibration, power required, and collective blade angle increased

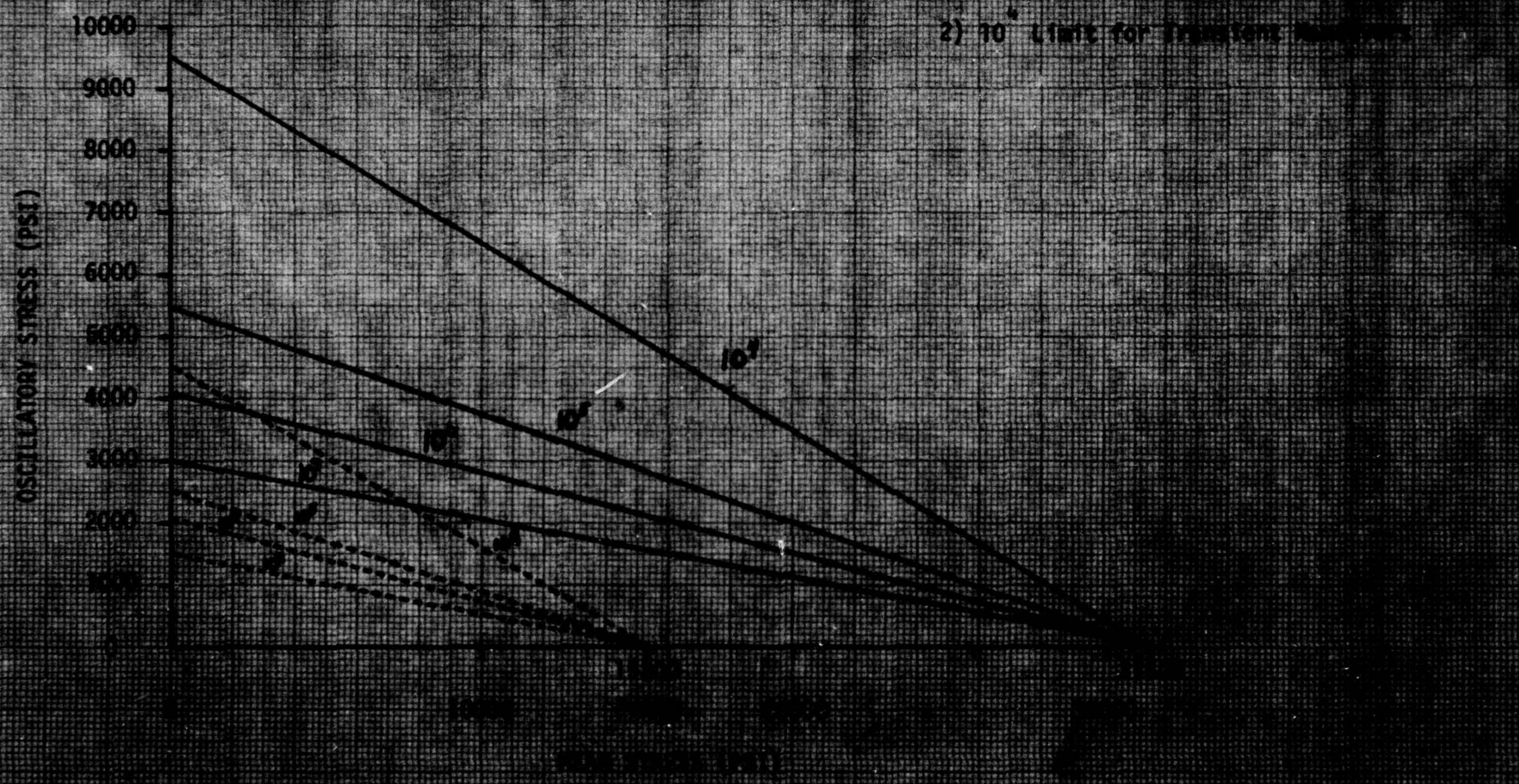
FIGURE E

MODIFIED GOODMAN DIAGRAM

FOR 6061-T6 SOLID LINE
FOR 6061-0 DASHED LINE

NOTE: 1) 10^8 Limit for

2) 10^4 Limit for



(fig. 8, app C). Alternating stresses in the aluminum sections were larger with spray ON than with spray OFF. Figures 8 and 9 illustrate the higher loads with spray ON. The stresses at location E reached the endurance limit specified in the safety-of-flight release at 138 KTAS during the envelope expansion tests with spray ON. However, during the cloud measurement flights, significantly higher alternating stresses were randomly encountered (mean stresses were unchanged). These higher alternating stresses could not be correlated to changes in gross weight, density altitude, rotor speed, water remaining in the tank, or water flow rate. Without the stiffener installed, the CH-47C/HISS would be restricted to 110 KTAS for all flight conditions.

20. With the stiffener attached, two conditions produced oscillatory stresses in the aluminum sections in excess of the endurance limit. At a rotor speed of 235 rpm, the stresses were above endurance limit at all flight conditions with the boom retracted or extended (figs. 19 and 20, app C). At 245 rpm, the stresses were excessive with the boom UP at airspeeds greater than 30 KTAS in any direction (figs. 21 and 22). Stresses at all other conditions (*ie*, boom DOWN, 245 rpm, greater than 30 KTAS) were acceptable. Excessive oscillatory stresses at 235 rpm at all flight conditions and at 245 rpm with the boom retracted at greater than 30 KTAS constitute a shortcoming. All flights should be conducted at 245 rpm. During flight with the boom retracted, airspeed in any direction should be limited to 30 KTAS.

21. Weights were attached to the lower horizontal boom in an attempt to change the boom natural frequency and damping to reduce alternating stresses. During a ground run, weights were attached to the boom as shown in table 4. At each weight configuration, the boom was deflected, then released, and the frequency and damping of the subsequent oscillation measured. The test was repeated at various rotor speeds. The lowest response at operational rotor speeds was with 25 pounds attached to the center of the lower boom. This configuration was flight tested and appeared satisfactory in a hover with boom UP. With boom DOWN, however, 3/rev alternating stresses reached ±2610 psi at location H, ±5080 psi at location E, and ±3690 psi at location J (endurance limit 2160 psi). These stresses were excessive and therefore this method of detuning was abandoned and a stiffener was designed.

Boom Extension and Retraction

22. The spray boom was successfully extended and retracted at a hover and at 10, 20, 30, and 40 KTAS. Extension and retraction were attempted at 50 KTAS but could not be accomplished. During extension attempts at this airspeed, the up-locks released

Table 4. Lower Boom Detuning Conditions.

Rotor Speed (rpm)	Weight (pounds) Applied to Lower Boom at Aircraft Buttline.						
	162 Left	81 Left	54 Left	Zero	54 Right	81 Right	162 Right
235				25			
245				25			
235		25				25	
245		25				25	
235		25		25		25	
245		25		25		25	
235	25			25			25
245	25			25			25
235			25	25	25		
245			25	25	25		
245			10	10	10		
245		10		10		10	
235	10			10			10
245	10			10			10
245				30			
245				20			

properly and the boom extended nearly all the way. However, the down-locks would not move into position until airspeed was reduced to 40 KTAS. Similarly, during retraction attempts, the down-locks would not release until airspeed was reduced to 40 KTAS. Boom extension times increased and retraction times decreased with increasing airspeed. Extension times ranged from 54 to 69 seconds, while retraction times were between 52 and 44 seconds. These results did not change when the extension/retraction system was modified.

23. Prior to modification of the extension/retraction system, the procedures for raising and lowering the boom were confusing and the boom status lights did not give an accurate indication of boom UP, DOWN, or LOCKED conditions. With the initial system, extending the boom required the copilot to first push the BOOM UP button to remove the weight of the boom from the aft latches so that the crew chief could manually release those latches. Once the latches were released, the BOOM DOWN button was pushed to extend the boom. Similarly, the first step required to retract the boom was to push the BOOM DOWN button. Throughout the procedure, the position of the boom and locking mechanisms had to be visually checked by the crew chief because the status lights did not give proper indications. This system was unacceptable and was modified by AAE.

Handling Qualities

25. The handling qualities of the CH-47C and the control margins remaining with the modified HISS were evaluated throughout these tests. Quantitative data were gathered prior to the stiffener installation to evaluate simulated hovering in winds and control positions in trimmed forward flight. These data are presented in figures 1 through 4, appendix C. Handling qualities in the low-speed flight regime and in trimmed forward flight were essentially unchanged from those of the basic CH-47C and the control margins were adequate. The variation of longitudinal cyclic control position with airspeed provided inadequate cues when trimming to a predetermined airspeed. The increasing aft control required with increasing airspeed is a shortcoming of the CH-47C and is unchanged by the addition of the HISS.

26. The maneuvering and static lateral-directional stability characteristics of the aircraft were evaluated qualitatively at 70 and 100 knots indicated airspeed (KIAS) at pressure altitudes of approximately 7000 and 10,000 feet. These characteristics appeared to be unaffected by the installation of the modified HISS. Adequate cues were available to the pilot to maintain the desired heading and ground track or turn rate. Within the scope

of this evaluation, the handling qualities of the CH-47C with the modified HISS installed are adequate for the proposed mission, with or without the stiffener.

OPERATING CHARACTERISTICS

General

27. The spray boom is extended and retracted by two hydraulically operated rams attached to either end of a torque tube located in the cabin section. Control of the hydraulic rams is through an electrical control panel located on the copilot side of the angled console. This control panel also incorporates the emergency jettison switch for boom and water, an arming switch for jettison capability, and a boom air switch that controls engine bleed air to the system. During the evaluation, it was found that 40 KIAS was the maximum airspeed for extending and retracting the boom because the down-locks would neither lock nor unlock at higher indicated airspeeds. A CH-47C aircraft checklist (TM 55-1520-227-10CL) was modified to incorporate the HISS operational checks into the standard preflight, start-up, shut-down, and emergency procedures. Additional information and procedures for and about extending and retracting the boom, spraying, and in-flight emergencies are detailed in paragraphs 28 through 32. Since the HISS is a special type of test equipment, and will be operated by personnel specially trained for a specific mission, the operating characteristics are satisfactory. If, however, other uses for the HISS are conceived, additional refinement of the operating characteristics will be necessary to issue a safety-of-flight release for the new mission.

Extending the Boom

28. Extending the boom requires coordination between the copilot and crew chief. Once the aircraft has been stabilized at the extension airspeed, the copilot activates the BOOM DOWN switch and the crew chief pulls the manual up-lock releases and places the pull rings over catches located adjacent to the releases. There are two manual up-lock releases, one on each side of the aircraft at floor level. The crew chief must bend over, pull the release ring, place the ring over the retaining catch, stand and walk to the other side of the aircraft, and repeat the procedure. It should be noted that the release rings must be left over the retaining catch while the boom is extending because the control box logic is such that the boom will stay in or return to the retract position if the up-lock releases are in any other position. As the boom begins to traverse, the BOOM UP and the LOCKED lights

on the control panel extinguish. Once the boom is fully extended, the boom down-locks engage and cause the BOOM DOWN and the LOCKED lights to illuminate. As the boom extends, the aircraft slowly pitches nose-down, requiring continual retrimming. This continual retrimming is barely noticeable because of the pilot workload with the poor handling qualities of the aircraft at low airspeed. The time required for the boom to extend is approximately 1 minute. Operating procedures for extending the boom are satisfactory.

Spraying

29. Operating procedures for the HISS were prepared and attached to the water tank located in the cabin section. The procedure requires the copilot to place the boom air switch in the ON position, and the crew chief to set air pressure and water flow rate to the desired test conditions. The crew chief may also purge the water line at the completion of a spray mission by stopping the water flow and diverting bleed air into the water line. While transiting to and from the test altitude the bleed air switch will be in the ON position, and bleed air will be diverted into the water line to preclude freezing of the residual water that collects in the lower portions of the boom. Under these conditions the pilot must be especially cognizant of engine temperature limits, since there is a 30°C rise in power turbine inlet temperature with a corresponding loss of power available (approximately 3 percent registered at the pilot torquemeter). Operating procedures for the spray system are satisfactory.

Retracting the Boom

30. Retracting the boom requires coordination between the copilot and crew chief. Once the aircraft has been stabilized at the retraction airspeed, the copilot advises the crew chief to remove the up-lock release pull rings from the catches located adjacent to the releases. The copilot then activates the BOOM UP switch which causes the down-locks to disengage, extinguishing the BOOM DOWN and LOCKED lights, and starts the boom traversing toward the BOOM UP position. Once the boom has engaged the up-locks, a BOOM UP and a LOCKED light illuminate on the control panel. As the boom retracts, the aircraft slowly pitches nose-up, requiring continual retrimming which is again barely noticeable. Time required for boom retraction is approximately 1 minute. Operating procedures for retracting the boom are satisfactory.

In-Flight Emergencies

31. In view of the large number of in-flight emergencies that can arise, no attempt will be made to dictate specific procedures

to be executed; therefore, the following discussion is to be viewed as advisory in nature, and should be tempered with the specifics of the situation. If it is determined that the aircraft and/or crew are in danger, the pilot may elect to jettison the boom, the water, or both boom and water. In-flight jettison of the boom and/or water is accomplished by activating the guarded jettison switch. Ground jettison of the boom system showed that the explosive bolts in the boom system fired and released simultaneously. In-flight boom jettison tests were not performed. In-flight jettison of the water was accomplished and a very slight trim change was experienced.

32. Should the boom transit part way and come to a stop, the copilot can activate the red BOOM STOP switch on the control panel, and then activate the switch for the direction he wishes the boom to move. If several attempts do not precipitate movement, the copilot should then activate the opposite direction switch. Barring movement in any direction, the crew chief has a manual override switch which can be used to retract the boom. Assuming that the manual override is ineffective, the hydraulic lines to the hydraulic rams can be disconnected and a gentle landing accomplished so as to force the boom up. This technique is not recommended at high gross weights. As a last resort, the boom can be jettisoned using the procedure outlined above.

Spray Cloud Measurement

33. Measurement of spray cloud properties was accomplished at a 7000-foot pressure altitude at the conditions shown in table 2. The LWC and water droplet size distributions in the cloud were measured using a laser spectrometer mounted in a Piper Aztec aircraft flying behind the CH-47C. Relative position of the two aircraft was determined with a rear-facing radar altimeter and theodolite mounted in the CH-47C. The LWC and droplet size distribution measurements were taken by Environmental Research and Technology, Inc. (ERT) under contract to the Army. An analysis of the results was published by ERT (ref 12, app A). Because of various problems discussed in the ERT report, the variation of LWC could not be related to airspeed, water flow rate, relative humidity, position in the cloud, or distance behind the CH-47C. The droplet size distribution in the HISS cloud is similar to that found in a precipitating tropical cloud, although the droplet concentration is quite low for such a cloud. The excessively large droplet size distribution generated by the HISS is a shortcoming. A procedure for determining water flow rate for a desired LWC is outlined in appendix E.

34. Qualitatively, the cloud appears to be of sufficient size to totally immerse a UH-1H helicopter in an icing environment. During these tests the CH-47C wake turbulence in the spray cloud was evaluated. A UH-1H helicopter was flown at various vertical and horizontal positions in the cloud at several distances behind the CH-47C. At stand-off distances up to 300 feet the UH-1H was virtually unaffected by CH-47C wake turbulence. At 80 KIAS it was difficult to stabilize in the cloud at distances greater than 300 feet, but the maximum usable stand-off distance increased with airspeed. The ease of stabilizing in the spray cloud is greatly increased in the modified HISS as compared to the original system. The minimum usable standoff distance was 150 feet. This is the distance at which the clouds generated by the upper and lower spray booms converge.

CONCLUSIONS

35. The modified HISS, with the lower boom stiffener and tape applied, is airworthy within a restricted CH-47C flight envelope.

36. Dynamic response of the boom system to gusts is satisfactory (para 14).

37. Addition of the lower boom stiffener caused an apparently aerodynamically induced oscillation (para 15).

38. Changing the shape of the lower boom and stiffener with tape eliminated the aerodynamically induced oscillation (para 15).

39. Stresses in steel members of the boom system were acceptable (para 17).

40. With the boom UP and stiffener installed, stresses in the aluminum members of the boom system are acceptable at airspeeds less than 30 KTAS and a rotor speed of 245 rpm (para 20).

41. With the boom DOWN with stiffener and tape installed, stresses in the aluminum members are acceptable at all conditions tested at 245 rpm (para 20).

42. The modified boom extension/retraction system (including status lights) is satisfactory (para 24).

43. The handling qualities of the CH-47C with the modified HISS and stiffener installed are adequate for the proposed mission (para 26).

44. The variation of LWC of the cloud could not be experimentally correlated to changes in airspeed, water flow rate, relative humidity, position in the cloud, or distance behind the CH-47C (para 33).

45. Water droplet size distribution in the HISS cloud is similar to that found in a precipitating tropical cumuliform cloud (para 33).

46. The ease of stabilizing a test helicopter in the spray cloud is greatly increased in the modified HISS as compared to the original system (para 34).

47. Three shortcomings were identified.

SHORTCOMINGS

48. The following shortcomings were identified:

a. Excessive oscillatory stresses at 235 rpm at all flight conditions and at 245 rpm with the boom retracted at greater than 30 KTAS (para 20).

b. The increasing aft control required with increasing airspeed (para 25).

c. The excessively large water droplet size generated by the HISS (para 33).

RECOMMENDATIONS

49. The shortcomings listed in paragraph 48 should be corrected.

50. The adhesive tape (MIL-SPEC-PPP-T-0060C or equivalent) wrapped around the lower boom and stiffener should be part of the standard HISS configuration until a more permanent modification is tested (para 15).

51. The flight envelope contained in the CH-47C operator's manual should be used for the CH-47C/HISS with the following additional restrictions:

a. All flights should be conducted at a rotor speed of 245 rpm (para 20).

b. With the boom retracted, maximum airspeed in any direction should not exceed 30 KTAS (para 20).

APPENDIX A. REFERENCES

1. Final Report, US Army Aviation Systems Test Activity, Project No. 72-35, *Helicopter Icing Spray System Qualification*, October 1973.

2. Letter, AVSCOM, AMSAV-EQI, 18 February 1975, subject: AVSCOM Test Request No. 75-04, Modified Helicopter Icing Spray System (HISS) Evaluation.

3. Contract, DAAJ01-74-C-1021 (P6C), awarded by US Army Aviation Systems Command to All American Engineering Company, 27 June 1974.

4. Handbook, All American Engineering Company, SM-280B, *Installation, Operation, and Maintenance Instructions, With List of Parts, Icing Conditions Simulation Equipment*, Change 1, November 1974.

5. Technical Manual, TM 55-1520-220-10, *Operator's Manual, Army Model CH-47B and CH-47C Helicopters*, 30 April 1969.

6. Letter, AVSCOM, AMSAV-EQI, 21 October 1975, subject: Safety of Flight Release (SOFR) to Conduct Flight Envelope Expansion Testing for the CH-47C With the Modified Helicopter Icing Spray System Installed (AEFA Project No. 75-04).

7. Message, AVSCOM, DRSAV-EQI, 191345Z May 1976, subject: Revised Safety of Flight Release (SOFR) to Conduct Flight Expansion Testing for CH-47C With the Modified Helicopter Icing Spray System (HISS) Installed and Stiffener Affixed to Lower Boom (AEFA Project No. 75-04).

8. Regulation, AVSCOM, No. 70-11, *Experimental Flight Testing by US Army Aviation Systems Test Activity*, 30 July 1969.

9. Letter, USAAMRDL, SAVDL-AM-T, 9 August 1974, subject: Dynamic Analysis of the Modified Spray Rig Configuration.

10. Disposition Form, USAAEFA, SAVTE-TA, 29 July 1975, subject: Test Operations and Safety Plan for Modified Helicopter Icing Spray System Qualification.

11. Basic Loads and Stress Report, All American Engineering Company, Report P-281, *Helicopter Icing Spray System (HISS) Dual Boom Modification*, Volumes I and II, September 1974.

12. Technical Report, Environmental Research and Technology, Inc., Document P-1840, *Characteristics of a Spray Plume*, March 1976.

13. Technical Report, Calspan Inc., No. CG-5391-M-1, *Measurement of the Microphysical Properties of a Water Cloud Generated by an Airborne Spray System*, December 1973.

APPENDIX B. TEST INSTRUMENTATION

COCKPIT INSTRUMENTATION

1. The following special instrumentation/equipment was provided to the flight crew:

Pilot Panel

Main rotor speed
Gas producer speed (one per engine)
Airspeed
Altitude
Outside air temperature
Total fuel used

Engineer Panel

Event switch
Record switch
Stop switch
Time code display

DATA ACQUISITION SYSTEM

2. The data acquisition system employed on the CH-47C helicopter incorporated a magnetic tape unit to record flight parameters. Vibration parameters were encoded using frequency modulation (FM). All other parameters were encoded using pulse code modulation (PCM). All the PCM data were telemetered to a ground station where 18 parameters were displayed and monitored in near real time during all flights.

TEST TRANSDUCERS

3. Test transducers were incorporated to monitor the parameters shown below.

Parameter	Location	Range
Longitudinal cyclic position	Beneath forward cockpit area	Zero to 100%

Lateral cyclic position	Beneath forward cockpit area	Zero to 100%
Roll rate	Same gyro as pitch rate, but using roll axis	100 deg/sec to -100 deg/sec
Yaw rate	Same gyro as pitch and roll rates, but yaw axis is used	60 deg/sec to -60 deg/sec
CG normal acceleration	On spray system platform	4g to -4g
Gas producer speed	N_1 engine No. 1 N_1 engine No. 2	70 to 105% 70 to 105%
Airspeed	Plumbed into static and airspeed air lines	Zero to 150 kt, 100 to 200 kt
Altitude	Plumbed into static air line	Zero to 20,000 ft
Outside air temperature	Beneath nose of ship	-30 to +30°C
Bleed air pressure	Plumbed into bleed air lines	-0.74 to 50 psi
Rotor speed		170 to 255 rpm
Pilot seat acceleration (vertical, lateral, longitudinal)	Mounted under pilot seat	-2g all axes
Rudder pedal position	Beneath forward cockpit area	Zero to 100%
Collective thrust lever position	Beneath forward cockpit area	Zero to 100%
Pitch attitude	On spray system platform	+46 to -46 deg
Roll attitude	Same gyro as pitch attitude, but using roll axis	+62 to -62 deg
Longitudinal automatic flight	Mounted within cockpit	Zero to 100%

control system (AFCS) position	and linked to AFCS servo linkage	
Lateral AFCS position	Mounted within cockpit and linked to AFCS servo linkage	Zero to 100%
Directional AFCS position	Mounted within cockpit and linked to AFCS servo linkage	Zero to 100%
Collective AFCS position	Mounted within cockpit and linked to AFCS servo linkage	Zero to 100%
Pitch rate	On spray system platform	+30 to -30 deg/sec
CG acceleration (vertical, lateral, longitudinal)		-2g all axes
Boom tip acceleration:		
Lateral		±10g
Longitudinal		±10g
Vertical		±10g

STRAIN GAGES

3. The following strain gage information is supplemented by figure 1.

AB_X (bending) gage factor 2.06	±600 microinches per inch (μin./in.)
AB_Z (bending) gage factor 2.06	±600 μin./in.
A_T (torsion) gage factor 2.05	±1300 μin./in.
BB_X (bending) gage factor 2.06	±2400 μin./in.
BB_Y (bending) gage factor 2.06	±2400 μin./in.
CB_X (bending) gage factor 2.06	±2400 μin./in.
CB_Y (bending) gage factor 2.06	±2400 μin./in.
C_T (torsion) gage factor 2.05	±2400 μin./in.

DB_X (bending) gage factor 2.06		±650 µin./in.
DB_Z (bending) gage factor 2.06		±650 µin./in.
EB_X (bending) gage factor 2.105		±1600 µin./in.
EB_Y (bending) gage factor 2.105		±1600 µin./in.
FB_X (bending) gage factor 2.06		±800 µin./in.
FB_Z (bending) gage factor 2.06		±800 µin./in.
F_T (torsion) gage factor 2.05		±115 µin./in.
GB_X (bending) gage factor 2.06		±1600 µin./in.
GB_Z (bending) gage factor 2.06		±1600 µin./in.
HB_X (bending) gage factor 2.105		±850 µin./in.
HB_Z (bending) gage factor 2.105		±850 µin./in.
JB_X (bending) gage factor 2.07		±800 µin./in.
JB_Z (bending) gage factor 2.07		±800 µin./in.

X Fore and aft motion with boom DOWN. Up and down motion with boom UP.

Z Up and down motion with boom DOWN. Fore and aft motion with boom UP.

Y Left and right motion

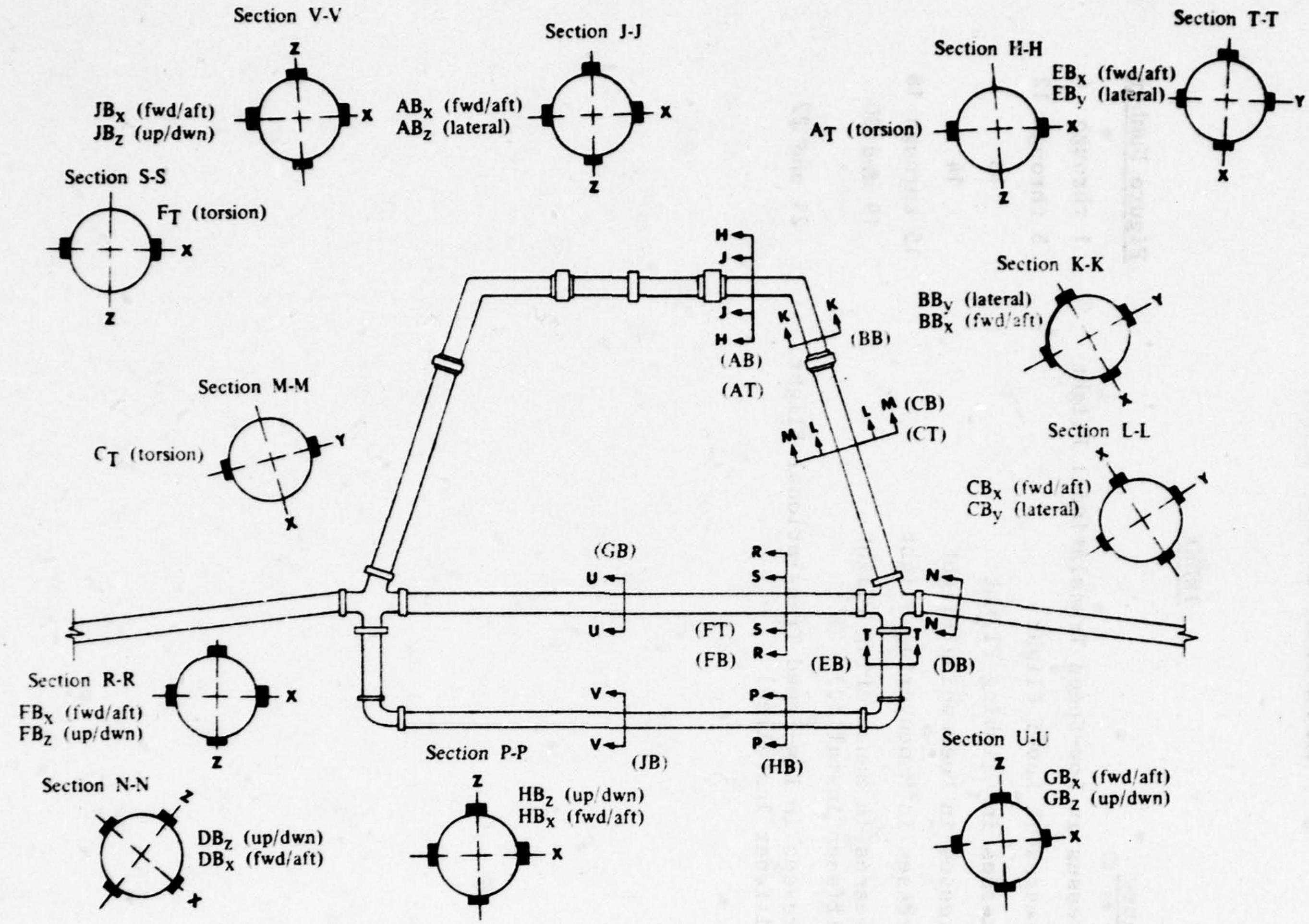


Figure 1. Spray Boom Instrumentation Schematic

APPENDIX C. TEST DATA

INDEX

FIGURE 1
LOW-SPEED FORWARD AND REARWARD FLIGHT
CH-47C/HISS USA S/N 15814

SYMBOL	AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	BOOM POSITION
○	38720	331.6(MID)	2980	18.0	246	DOWN
□	40880	330.8(MID)	2820	16.5	246	UP

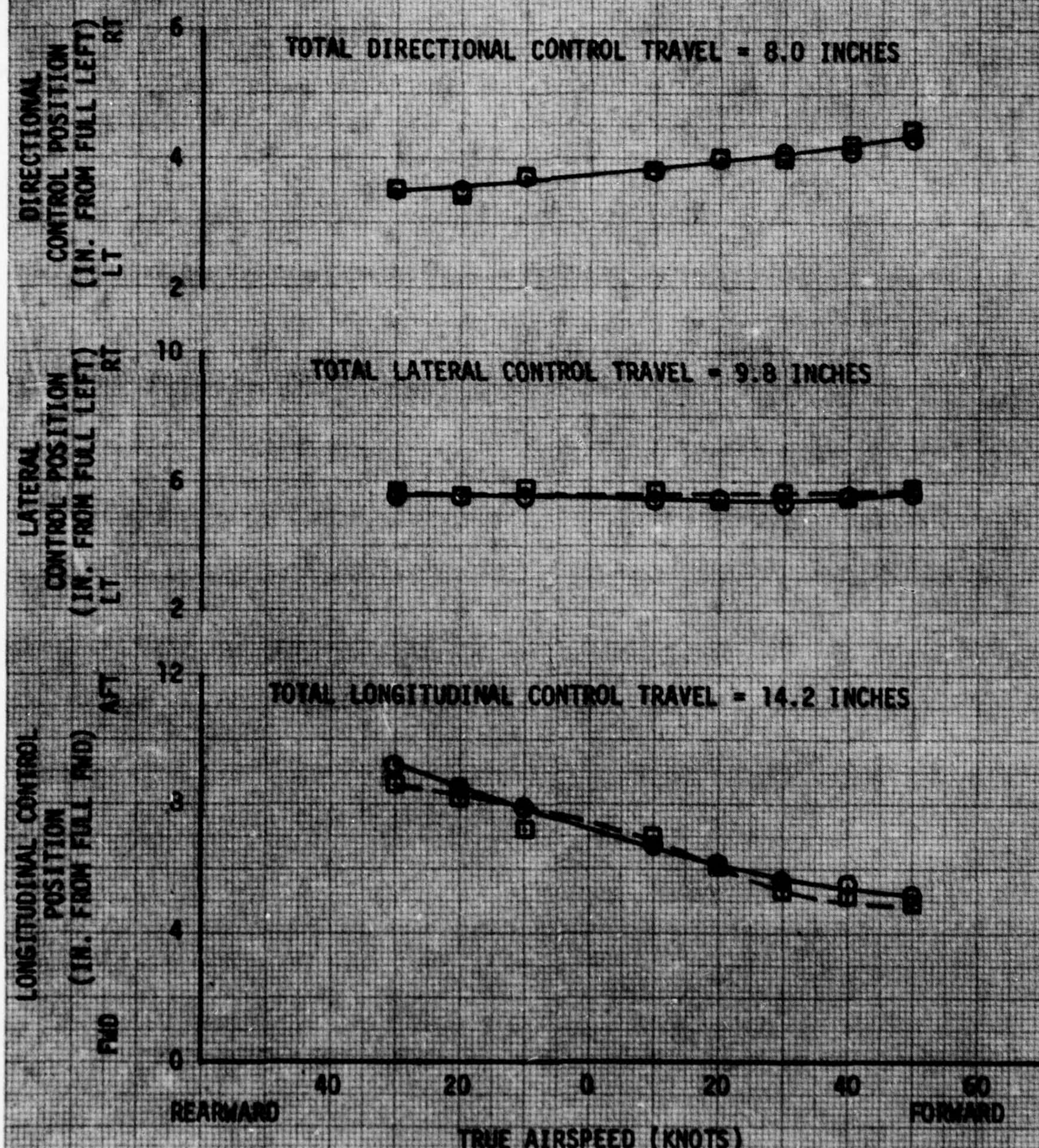


FIGURE 2
CONTROL POSITIONS IN SIDEWARD FLIGHT
CH-47C/HISS USA S/N 15814

SYMBOL	AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	BOOM POSITION
○	38700	331.5(MID)	2880	17.5	246	DOWN
□	40540	330.9(MID)	2640	15.5	246	UP

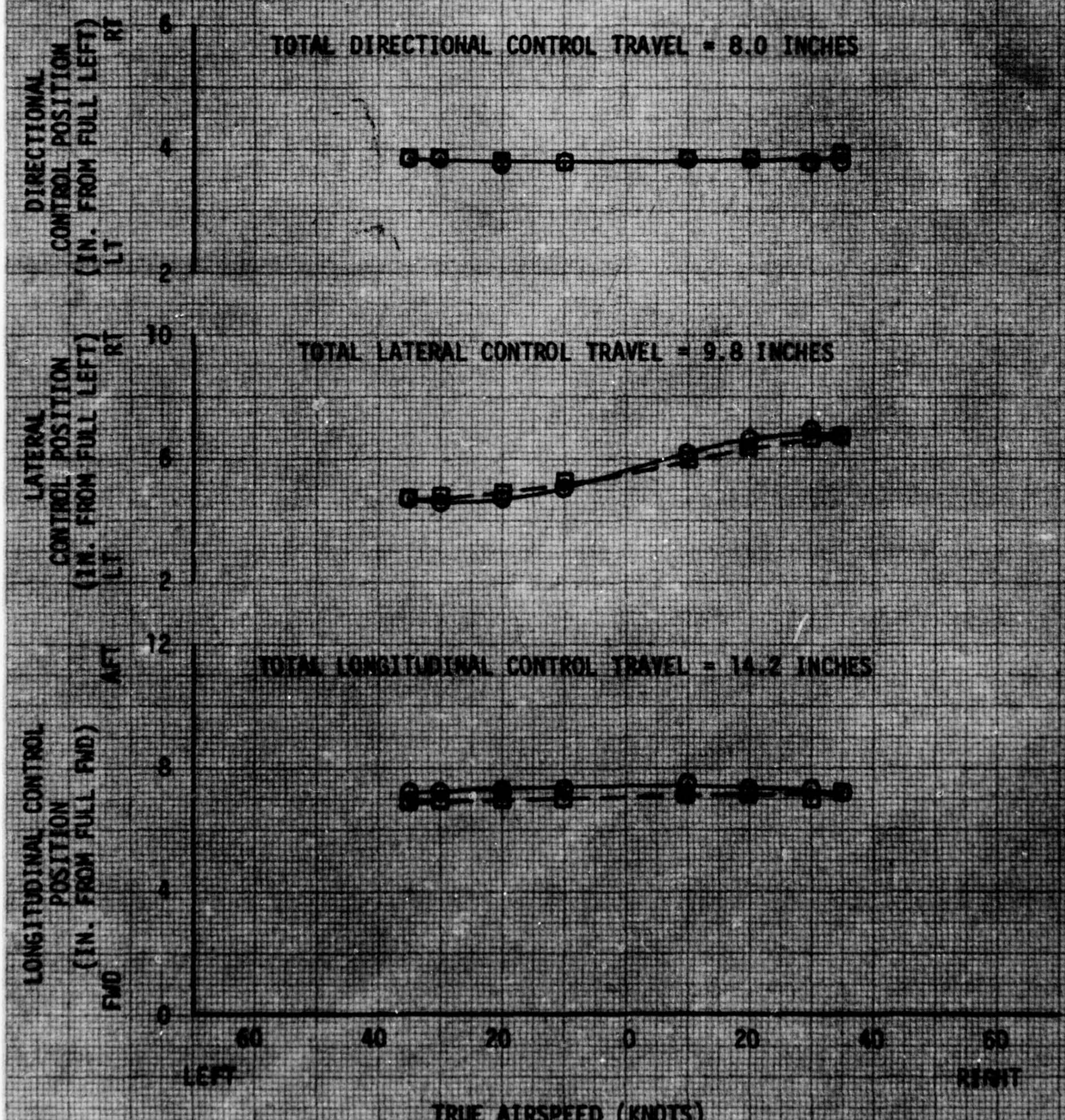


FIGURE 3

CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT

CH-47C/HISS USA S/N 15814

SYMBOL	AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	BOOM POSITION
○	31360	327.3(MID)	6600	-2.5	237	DOWN
□	29700	326.5(MID)	8040	9.5	237	UP

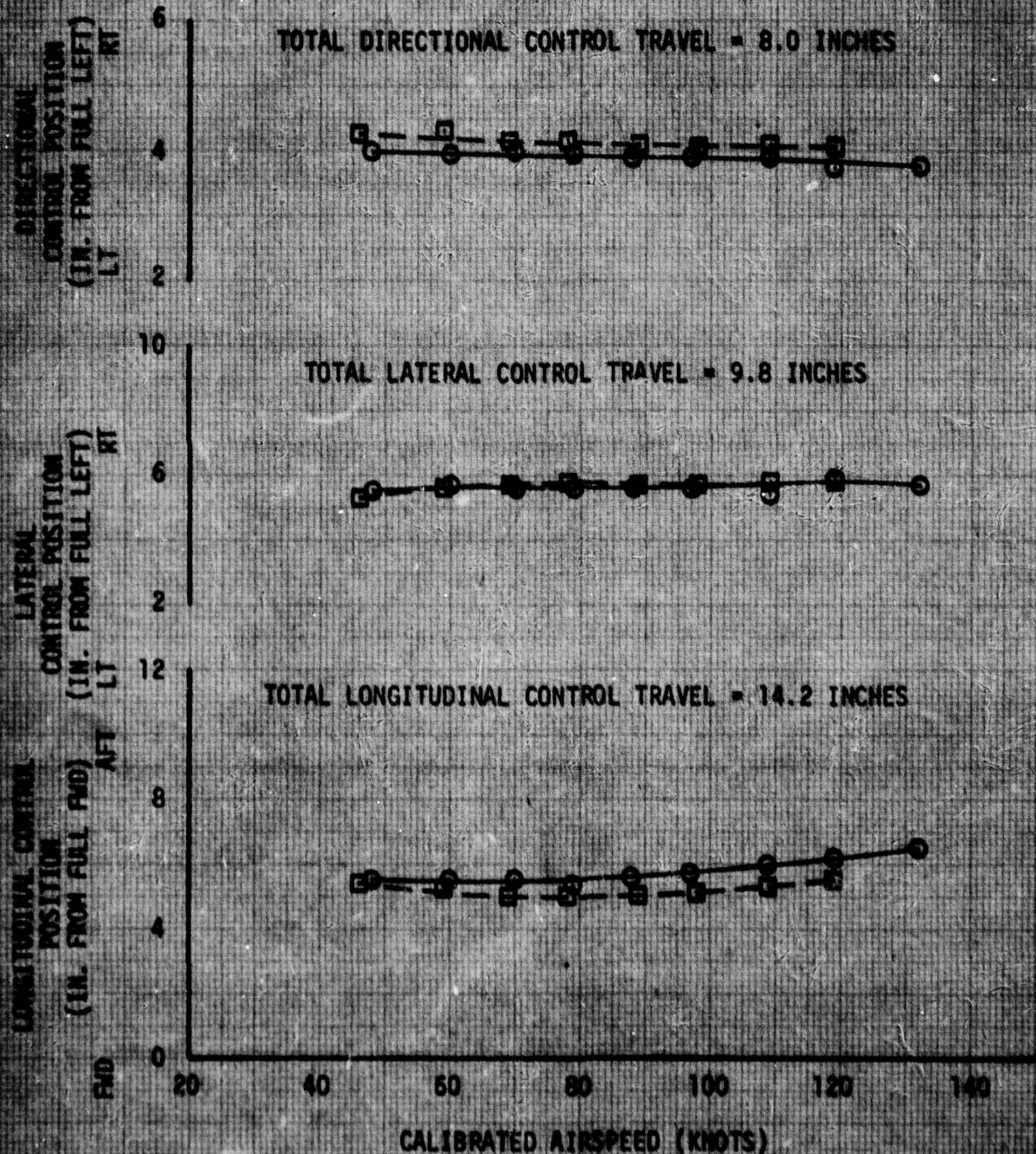


FIGURE 4
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
CH-47C/HISS USA S/N 15814

SYMBOL	AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	BOOM POSITION
○	40900	330.5(MID)	7700	6.5	246	DOWN
□	41400	330.4(MID)	8500	15.0	246	UP
■	41400	330.4(MID)	7720	6.0	246	UP

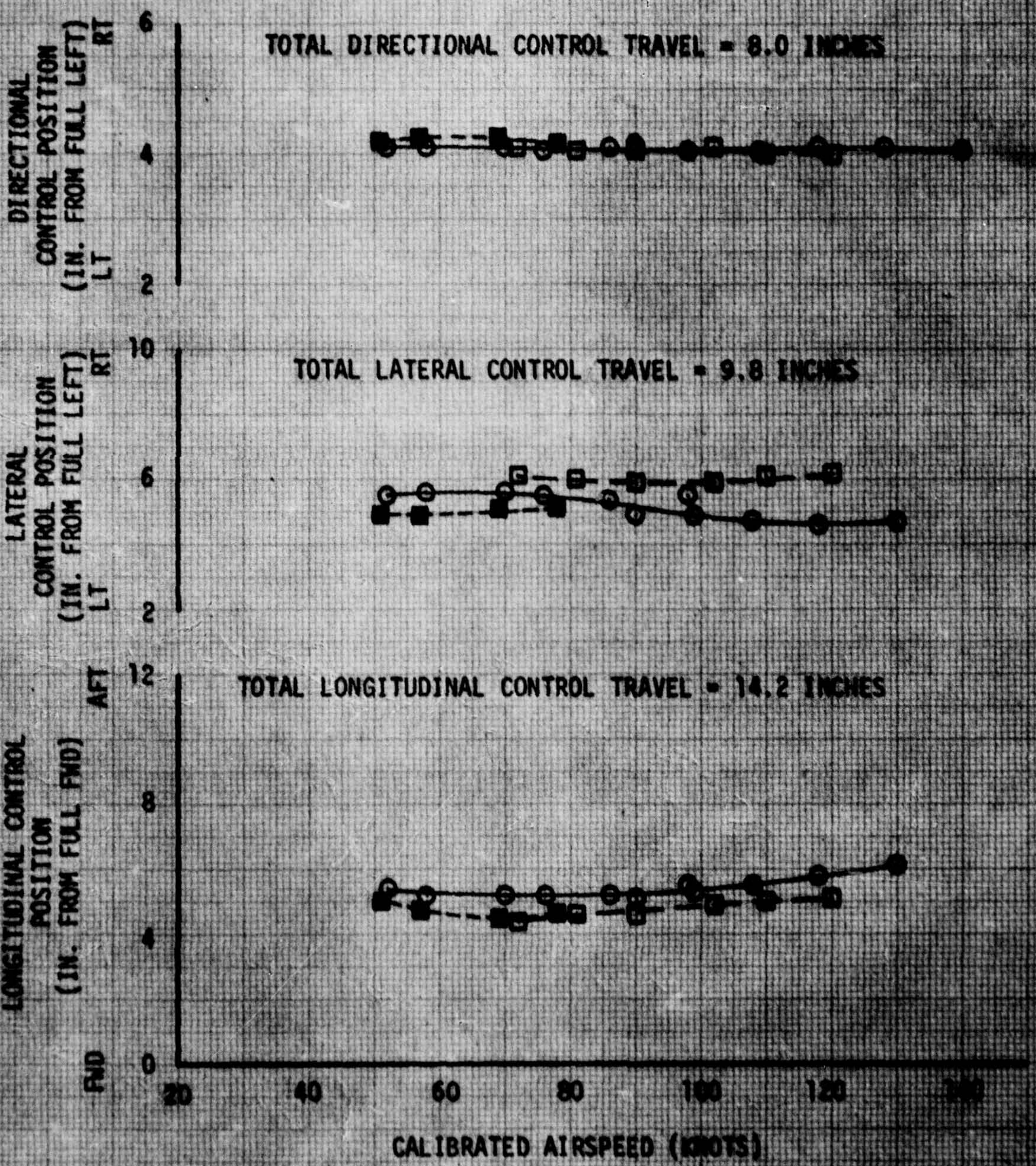


FIGURE 5
BOOM STRESSES IN LEVEL FLIGHT
CH-47C/HISS USA S/N 15814

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION (FS)	AVG HD (FT)	AVG OAT (°C)	AVG NR (RPM)	BOOM POSITION
29700	326.5(MID)	8040	9.5	237	UP

NOTES:
1. CIRCLES DENOTE MEAN STRESS.
2. SQUARES DENOTE ALTERNATING STRESS.
3. FLAGS DENOTE X-BENDING. (SEE FIG 1, APP B)
4. SPRAY OFF.
5. STIFFENER NOT INSTALLED.
6. SEE FIG. E FOR FATIGUE LIMITS.

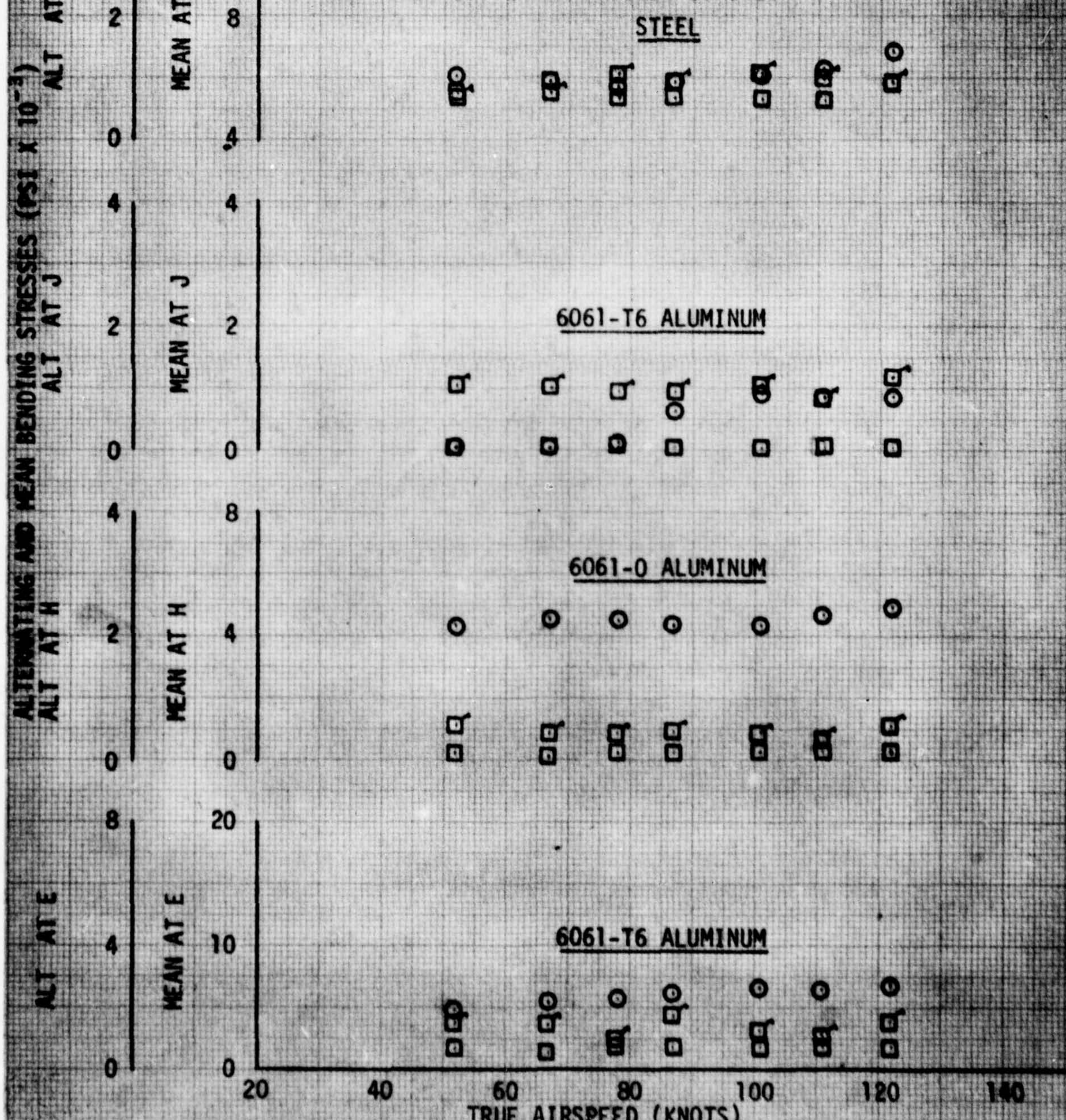


FIGURE 6
BOOM STRESSES IN LEVEL FLIGHT
CH-47C/HISS USA S/N 15814

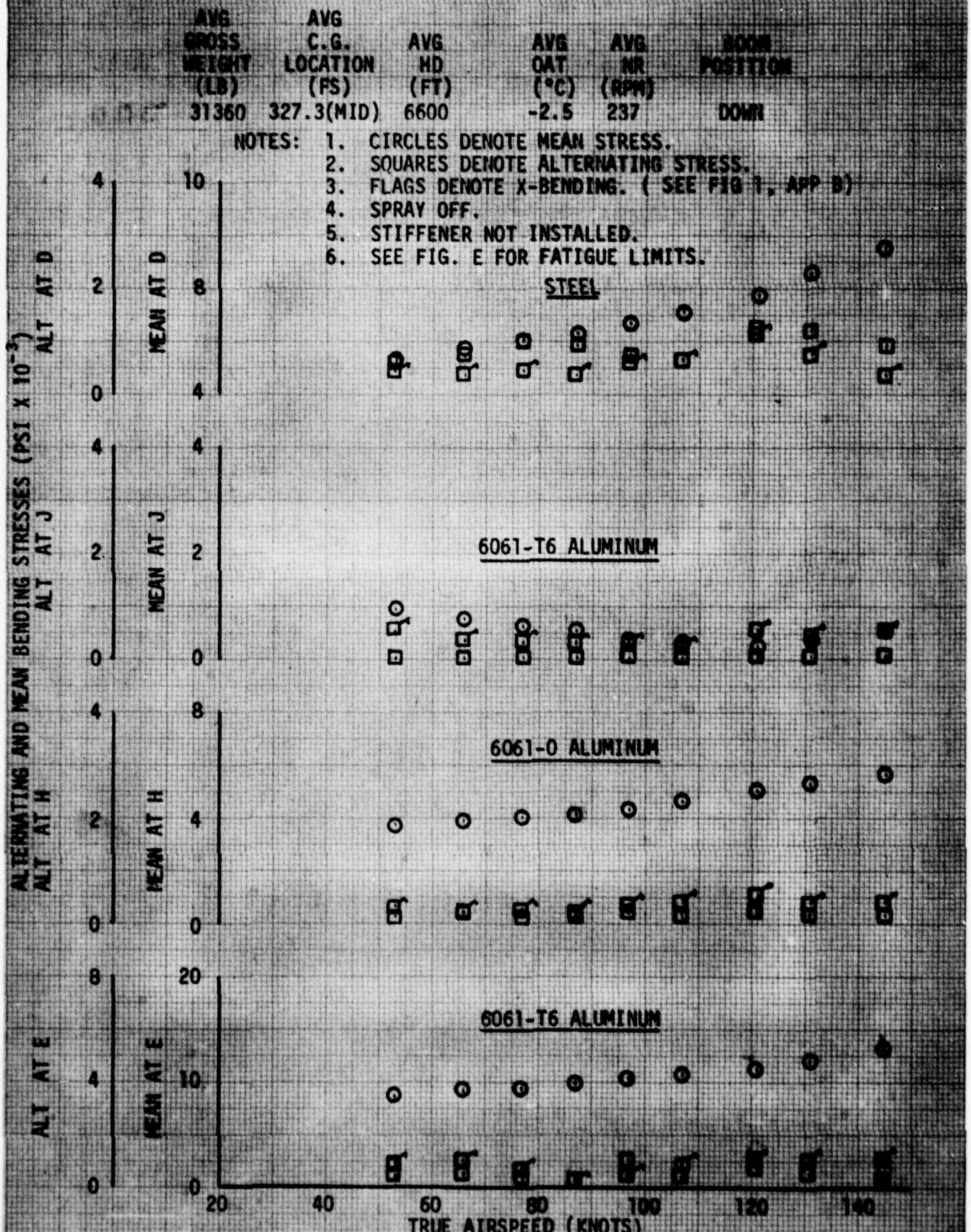


FIGURE 7
BOOM STRESSES IN LEVEL FLIGHT
CH-47C/HISS USA S/N 15814

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION (FS)	AVG HD (FT)	AVG OAT (°C)	AVG NR (RPM)	BOOM POSITION
41400	330.4(MID)	8100	10.5	246	UP

NOTES:
1. CIRCLES DENOTE MEAN STRESS.
2. SQUARES DENOTE ALTERNATING STRESS.
3. FLAGS DENOTE X-BENDING. (SEE FIG 1, APP B)
4. SPRAY OFF.
5. STIFFENER NOT INSTALLED.
6. SEE FIG. E FOR FATIGUE LIMITS.

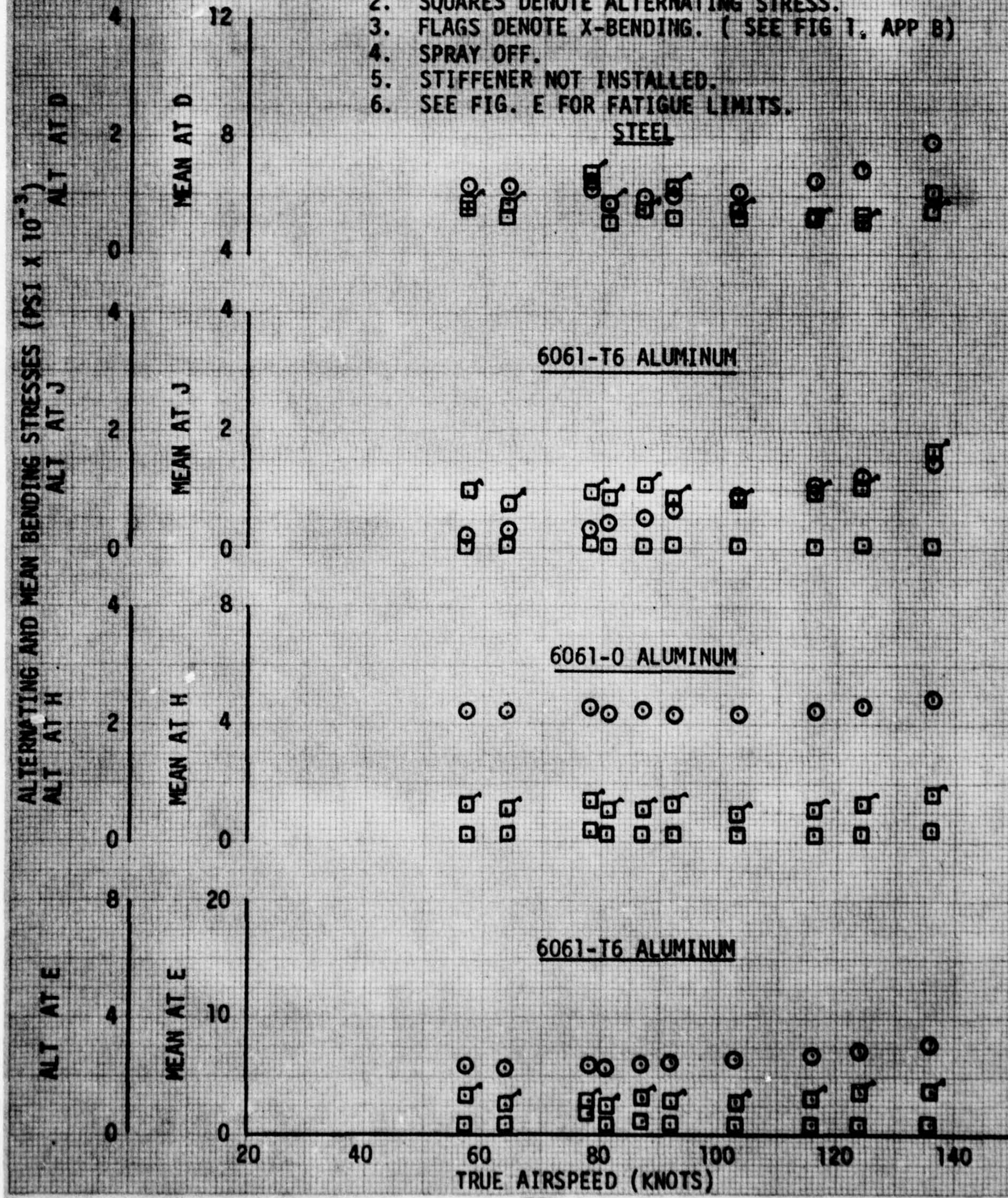


FIGURE 8
BOOM STRESSES IN LEVEL FLIGHT
CH-47C/MISS USA S/N [illegible]

[illegible]	AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION (FS)	AVG HD (FT)	AVG OAT (°C)	AVG NR (RPM)	BOOM POSITION
[illegible]	40900	330.5(MID)	7700	6.5	245	DOWN

NOTES:
1. CIRCLES DENOTE MEAN STRESS.
2. SQUARES DENOTE ALTERNATING STRESS.
3. FLAGS DENOTE X-BENDING. (SEE FIG 1, APP 8)
4. SPRAY OFF.
5. STIFFENER NOT INSTALLED.
6. SEE FIG. E FOR FATIGUE LIMITS.

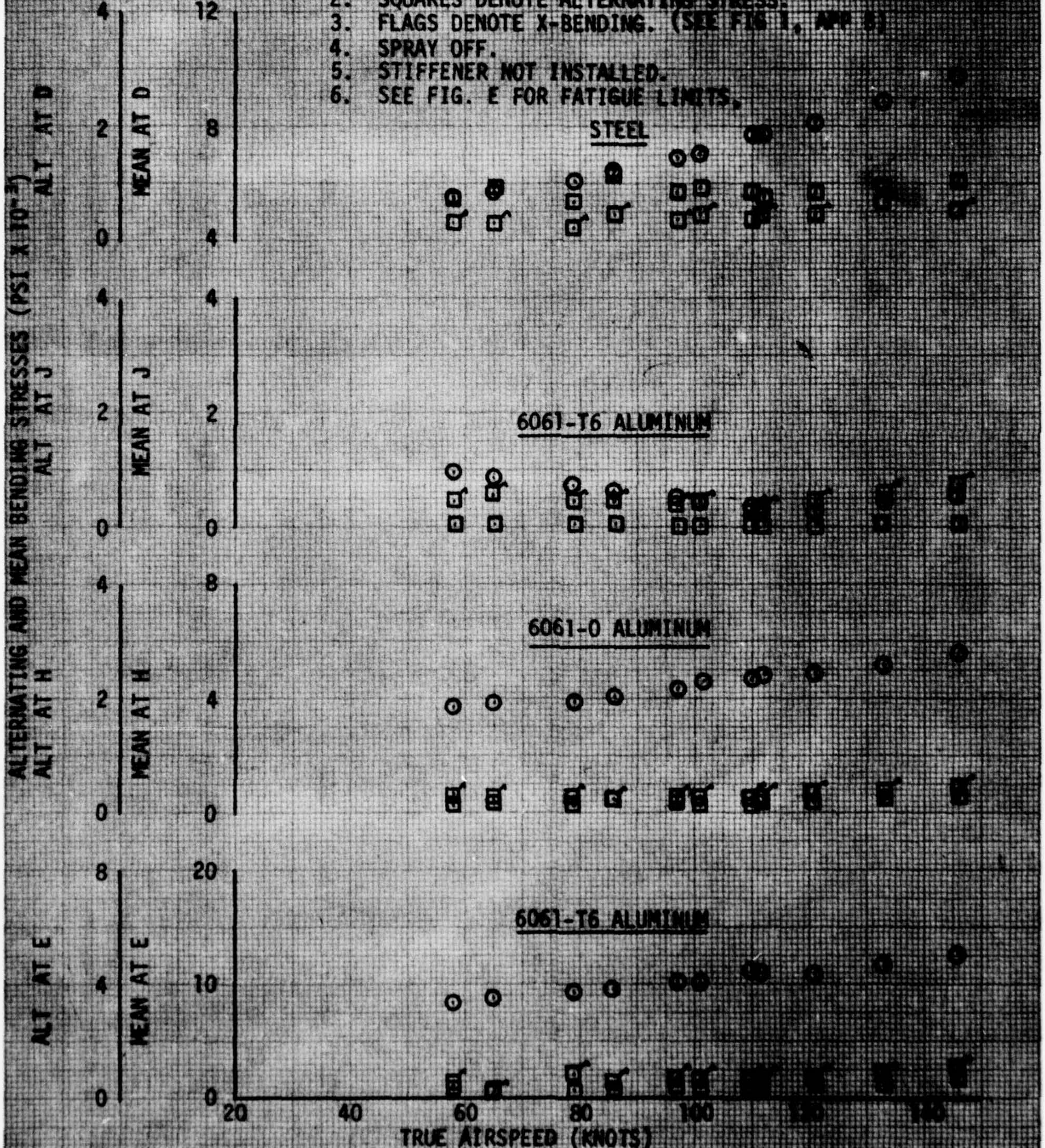


FIGURE 9
BOOM STRESSES IN LEVEL FLIGHT
CH-47C/HISS USA S/N 15814

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION (FS)	AVG HD (FT)	AVG OAT (°C)	AVG NR (RPM)	BOOM POSITION
35580	330.9 (MID)	8640	14.5	245	DOWN

NOTES:
1. CIRCLES DENOTE MEAN STRESS.
2. SQUARES DENOTE ALTERNATING STRESS.
3. FLAGS DENOTE X-BENDING. (SEE FIG 1, APP B)
4. SPRAY ON.
5. STIFFENER NOT INSTALLED.
6. SEE FIG. E FOR FATIGUE LIMITS.

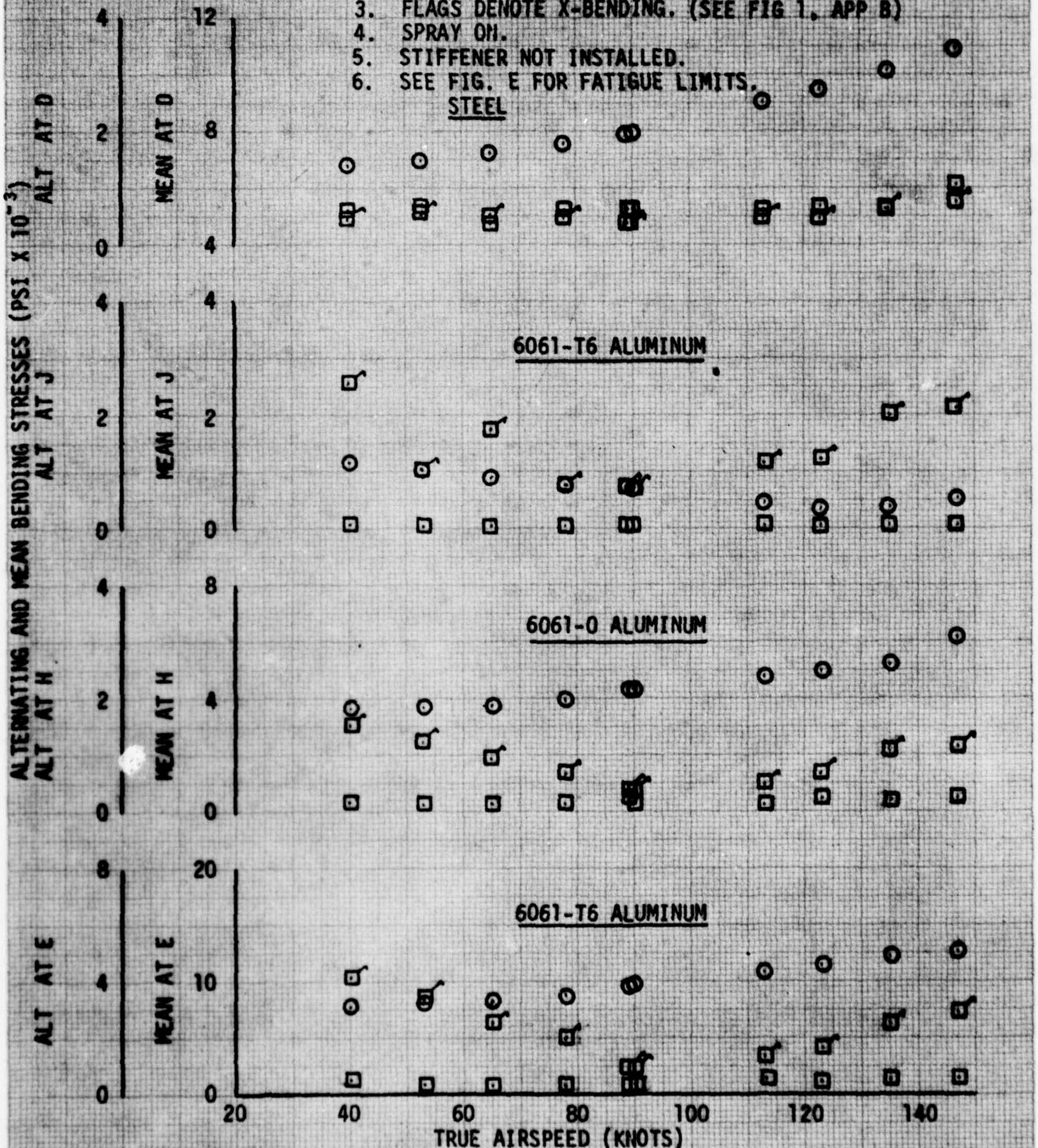


FIGURE 10

BOOM STRESSES IN LEVEL FLIGHT

CH-47C/HISS USA S/N 15814

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION (FS)	AVG HD (FT)	AVG OAT (°C)	AVG NR (RPM)	BOOM POSITION
40660	330.6(MID)	11780	7.0	247	UP

NOTES:
1) Circles denote mean stress
2) Squares denote alternating stress
3) Flags denote x-bending (See Fig. 1, App. B)
4) Spray Off
5) Stiffener not installed
6) See Fig. E for fatigue limits

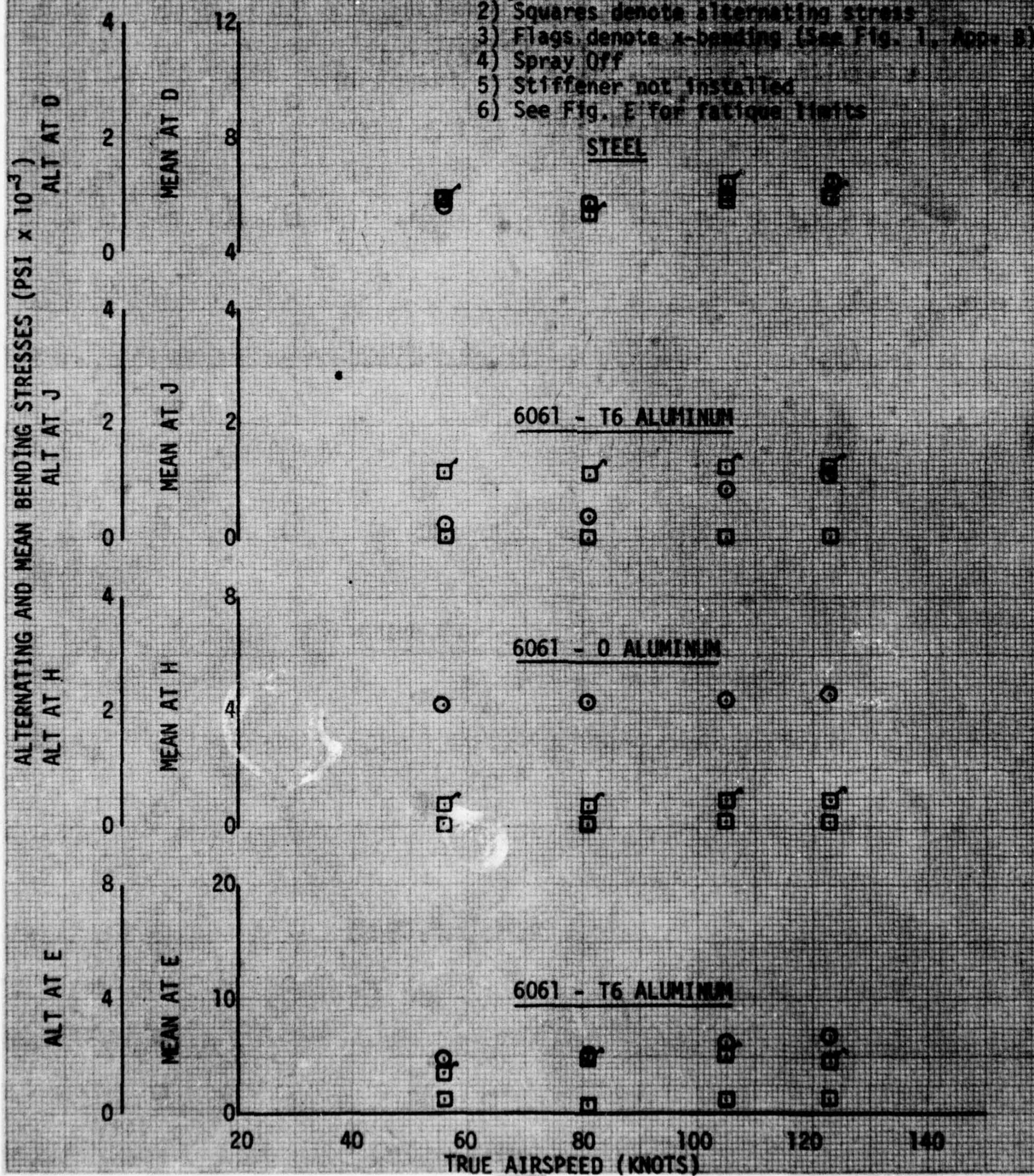


FIGURE 11

BOOM STRESSES IN LEVEL FLIGHT

CH-47C/HISS USA S/N 15814

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION (FS)	AVG HD (FT)	AVG OAT (°C)	AVG NR (RPM)	BOOM POSITION
39700	330.9(MID)	11860	7.0	246	DOWN

NOTES:
1. CIRCLES DENOTE MEAN STRESS
2. SQUARES DENOTE ALTERNATING STRESS
3. FLAGS DENOTE X-BENDING (SEE FIG 1, APP B)
4. SPRAY OFF
5. STIFFENER NOT INSTALLED
6. SEE FIG. E FOR FATIGUE LIMITS

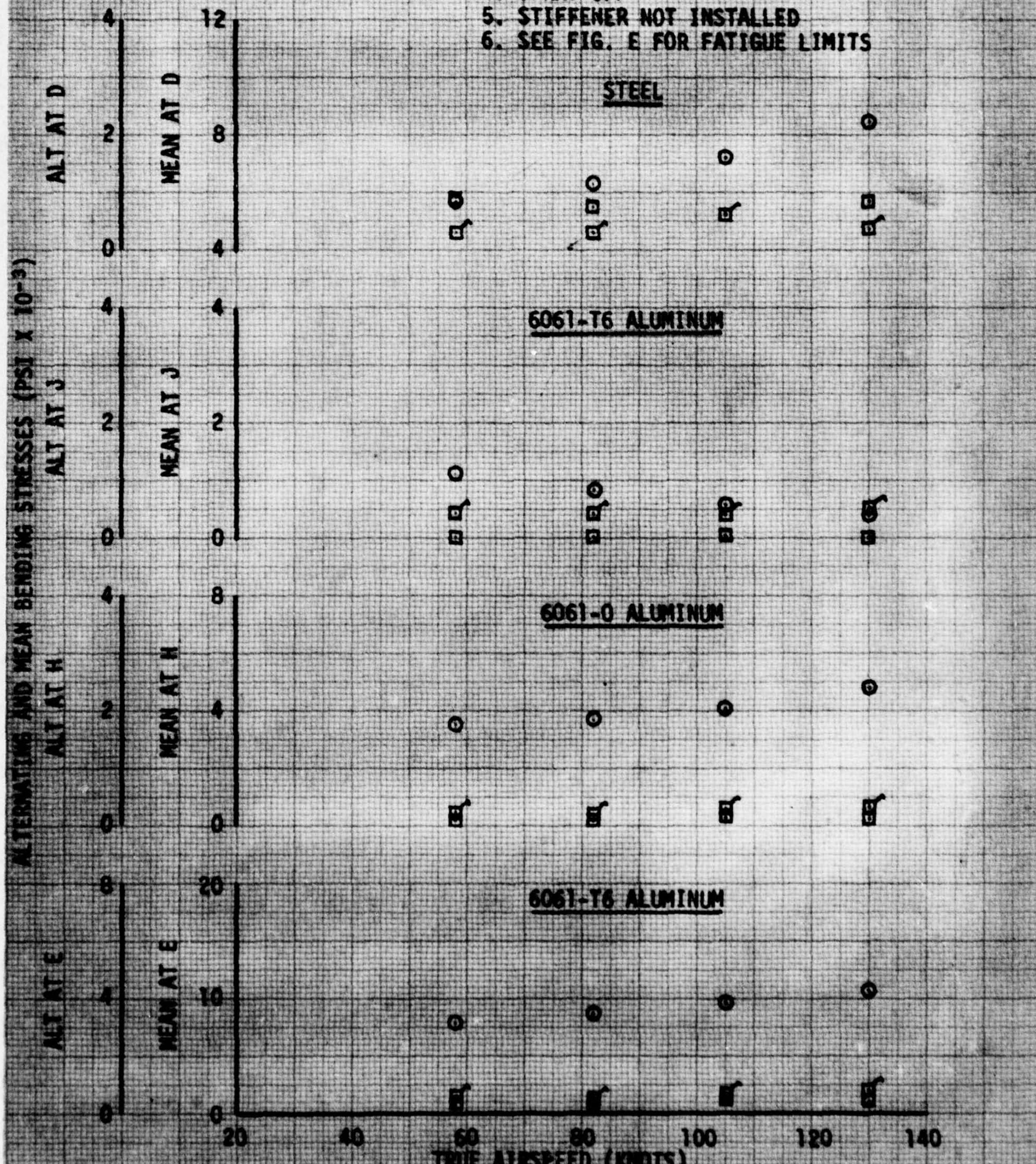
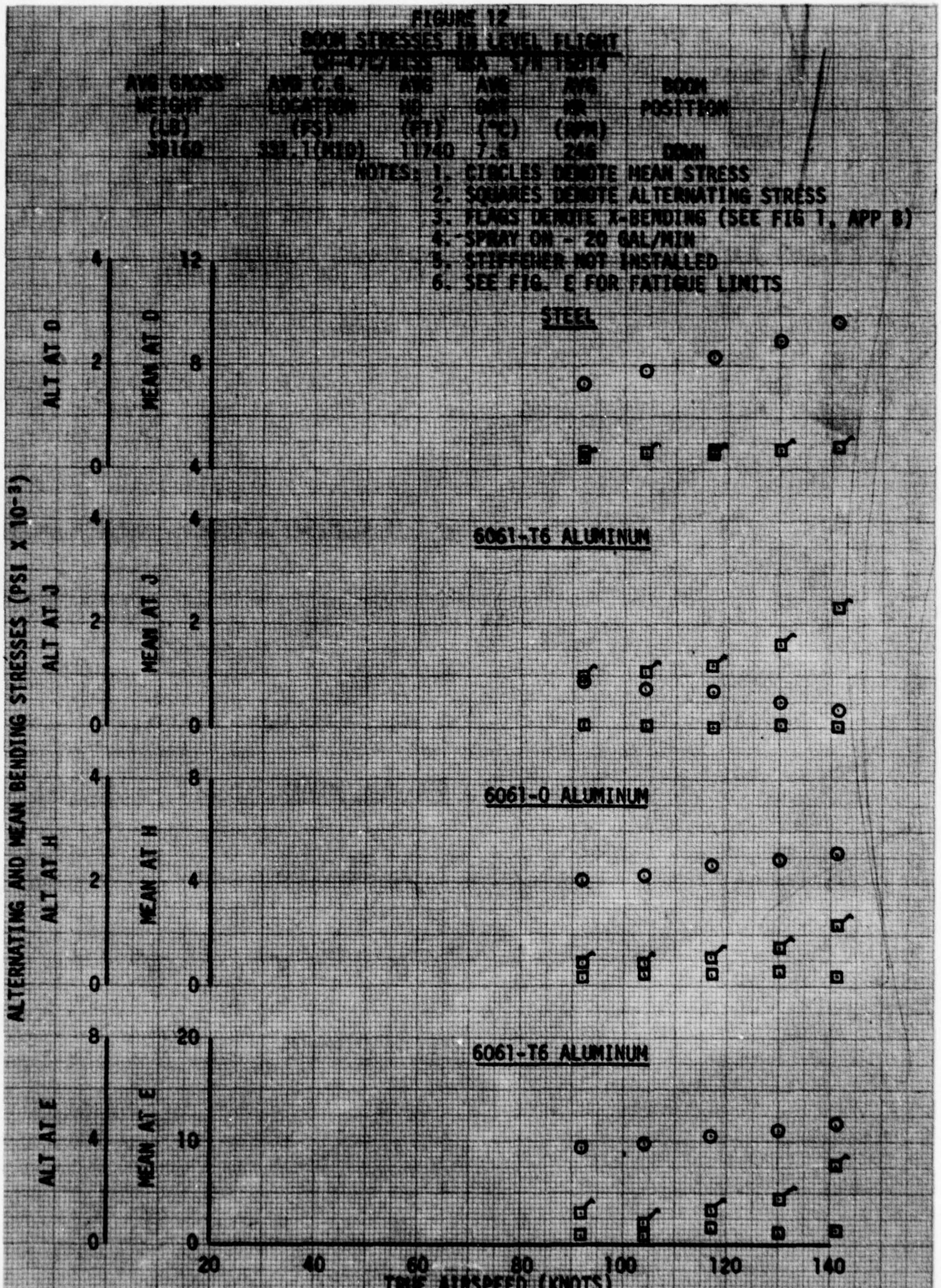


FIGURE 12
BOOM STRESSES IN LEVEL FLIGHT



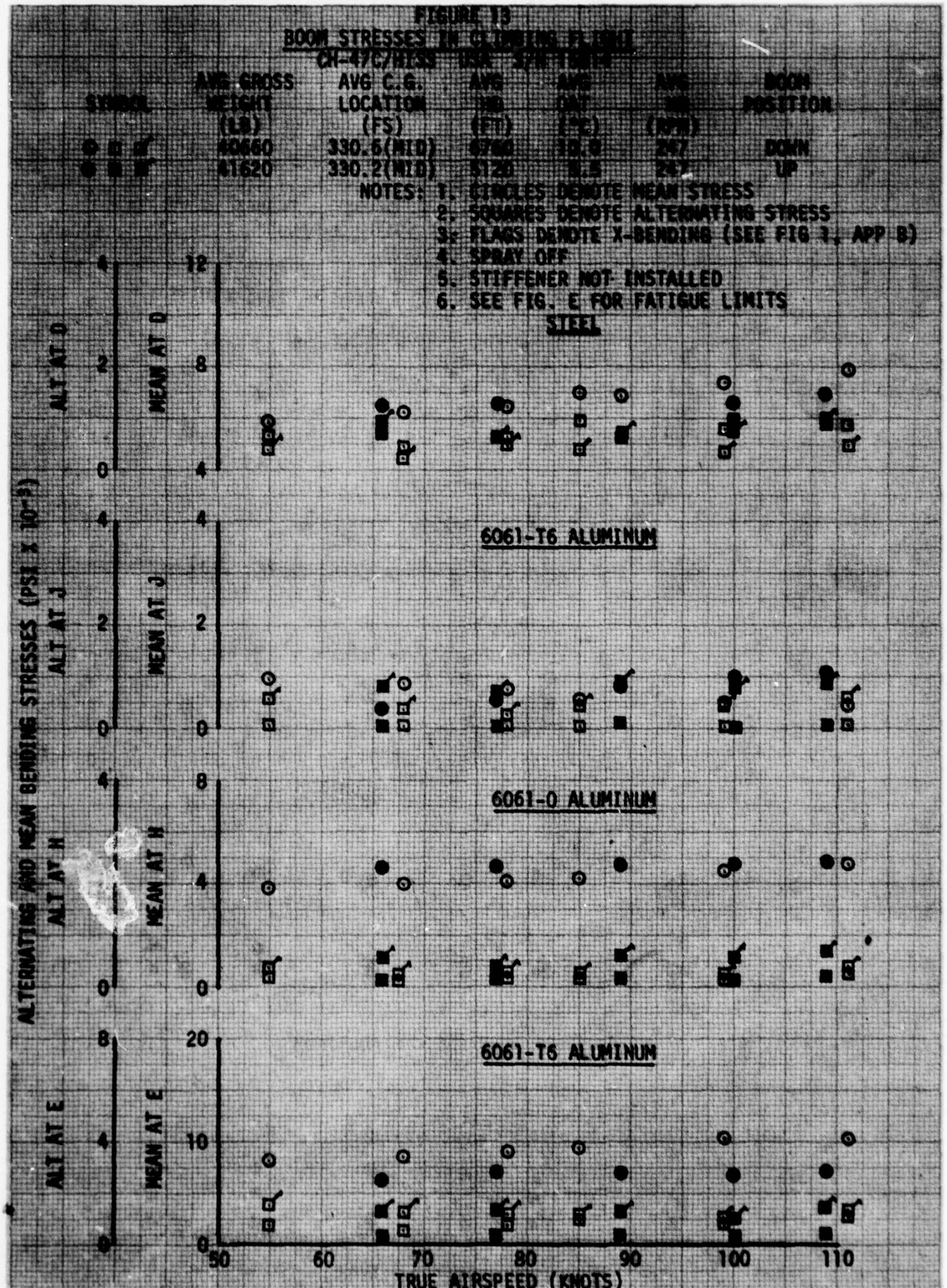


FIGURE 13
BOOM STRESSES IN CLIMBING FLIGHT
CH-47C/HISS USA S/N
SYMBOL
AVG GROSS WEIGHT (LB)
AVG C.G. LOCATION (FS)
AVG HD (FT)
AVG OAT (°C)
AVG RR (RPM)
BOOM POSITION
40660
330.6(MID)
6760
10.0
247
DOWN
41620
330.2(MID)
5120
5.5
247
UP
NOTES: 1. CIRCLES DENOTE MEAN STRESS
2. SQUARES DENOTE ALTERNATING STRESS
3. FLAGS DENOTE X-BENDING (SEE FIG 1, APP B)
4. SPRAY OFF
5. STIFFENER NOT INSTALLED
6. SEE FIG. E FOR FATIGUE LIMITS
STEEL
6061-T6 ALUMINUM
6061-0 ALUMINUM
6061-T6 ALUMINUM
ALTERNATING AND MEAN BENDING STRESSES (PSI x 10^-3)
ALT AT D
MEAN AT D
ALT AT J
MEAN AT J
ALT AT H
MEAN AT H
ALT AT E
MEAN AT E
TRUE AIRSPEED (KNOTS)
50
60
70
80
90
100
110

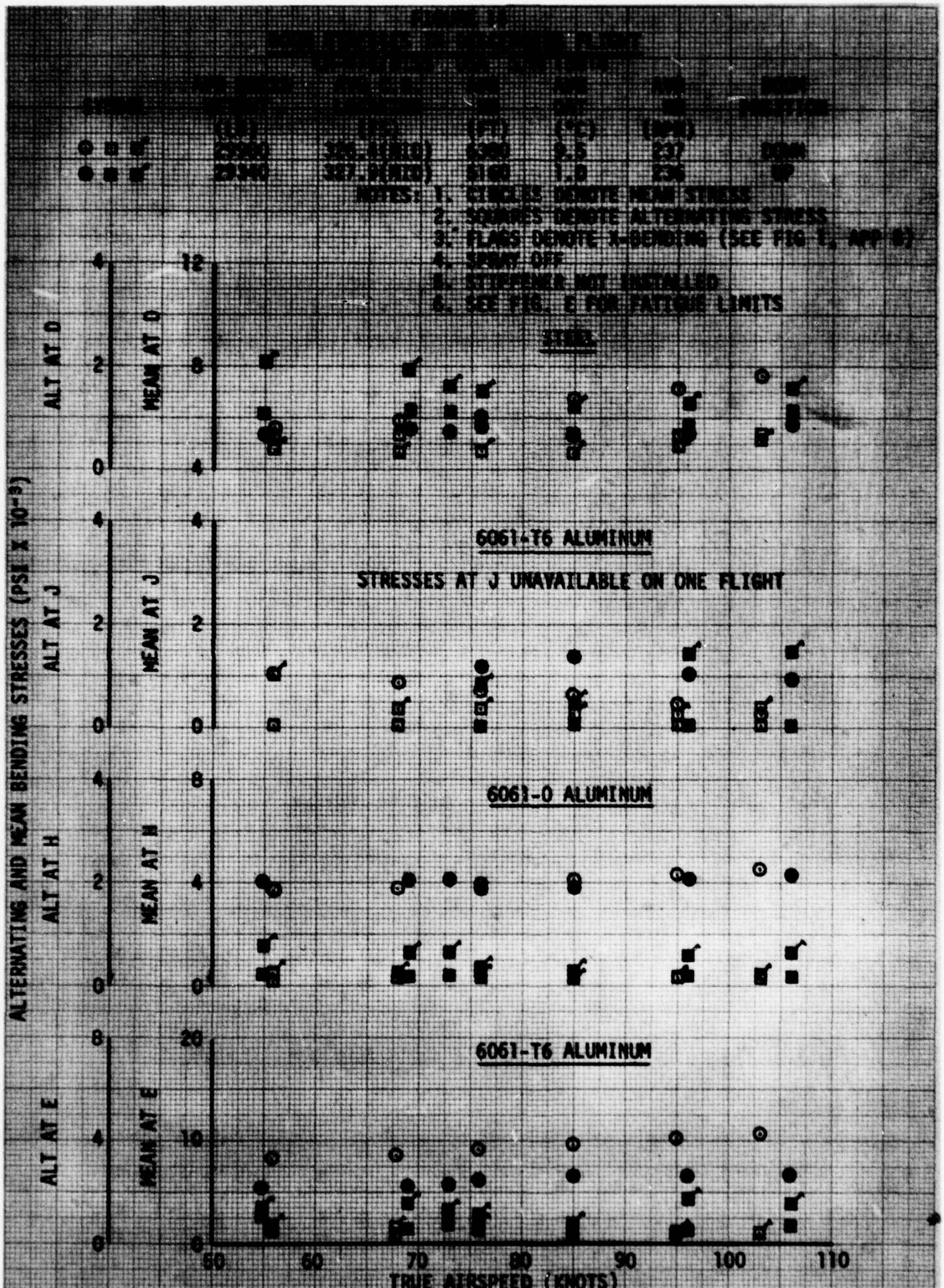

NOTES: 1. CIRCLES DENOTE MEAN STRESS
2. SQUARES DENOTE ALTERNATING STRESS
3. FLAGS DENOTE X-BENDING (SEE FIG 1, APP B)
4. SPRAY OFF
5. STIFFENER NOT INSTALLED
6. SEE FIG. E FOR FATIGUE LIMITS
STEEL
6061-T6 ALUMINUM
STRESSES AT J UNAVAILABLE ON ONE FLIGHT
6061-0 ALUMINUM
6061-T6 ALUMINUM
ALT AT D
MEAN AT D
ALT AT J
MEAN AT J
ALT AT H
MEAN AT H
ALT AT E
MEAN AT E
ALTERNATING AND MEAN BENDING STRESSES (PSI X 10^-3)
TRUE AIRSPEED (KNOTS)

FIGURE 15

BOOM STRESSES IN MANEUVERING FLIGHT

CH-47C/HISS USA S/N 15814

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION (FS)	AVG HD (FT)	AVG OAT (°C)	AVG NR (RPM)	TRIM TRUE A/S (KT)	BOOM POSITION
39400	330.9(MID)	8440	7.0	247	74	UP

NOTES:
1. CIRCLES DENOTE MEAN STRESS
2. SQUARES DENOTE ALTERNATING STRESS
3. FLAGS DENOTE X-BENDING (SEE FIG 1, APP B)
4. SPRAY OFF
5. STIFFENER NOT INSTALLED
6. SEE FIG. E FOR FATIGUE LIMITS

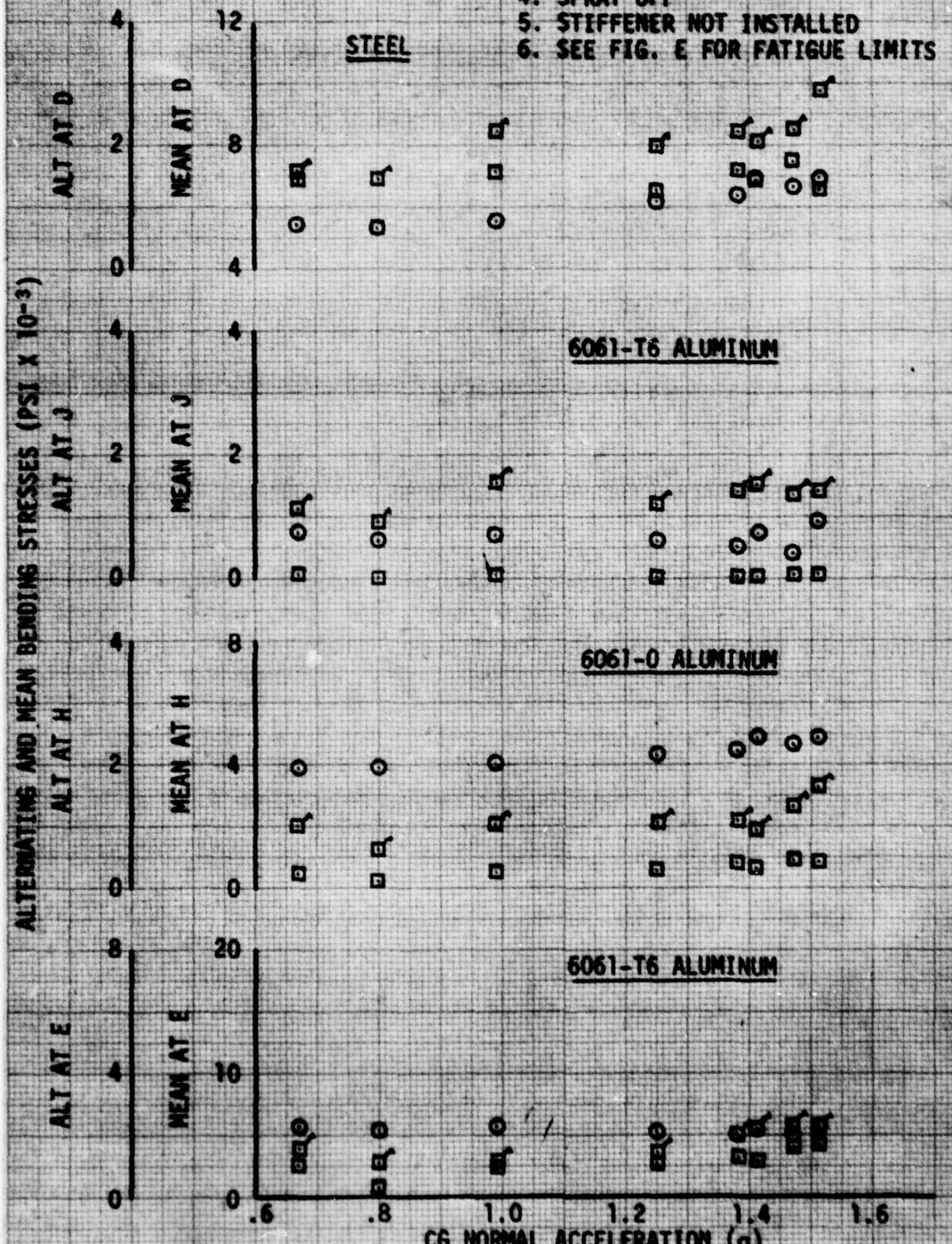


FIGURE 16

BOOM STRESSES IN MANEUVERING FLIGHT

[illegible] USA S/N [illegible]

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION (FS)	AVG HD (FT)	AVG OAT (°C)	AVG NR (RPM)	TRIM TRUE A/S (KT)	BOOM POSITION
40000	330.5(MID)	7600	9.0	246	70	DOWN

NOTES:
1. CIRCLES DENOTE MEAN STRESS
2. SQUARES DENOTE ALTERNATING STRESS
3. FLAGS DENOTE X-BENDING (SEE FIG 1, APP B)
4. SPRAY OFF
5. STIFFENER NOT INSTALLED
6. SEE FIG. E FOR FATIGUE LIMITS

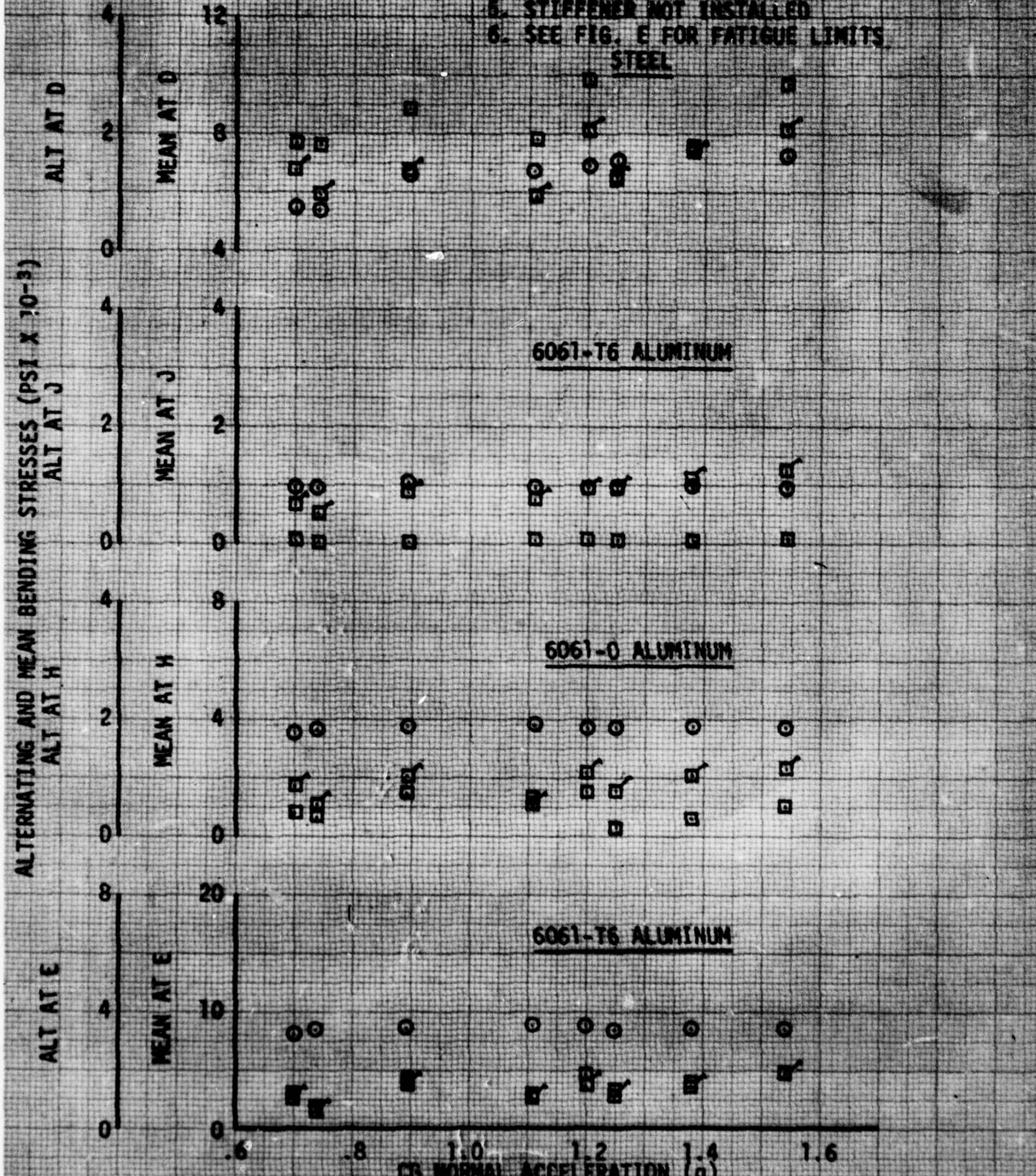


FIGURE 17
BOOM STRESSES IN MANEUVERING FLIGHT
CH-47C/HISS USA S/N 18814

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION (FS)	AVG HD (FT)	AVG OAT (°C)	AVG NR (RPM)	TRIM TRUE A/S (KT)	BOOM POSITION
39080	331.0(MID)	8220	9.0	247	107	UP

NOTES:
1. CIRCLES DENOTE MEAN STRESS
2. SQUARES DENOTE ALTERNATING STRESS
3. FLAGS DENOTE X-BENDING (SEE FIG 1, APP B)
4. SPRAY OFF
5. STIFFENER NOT INSTALLED
6. SEE FIG. E FOR FATIGUE LIMITS

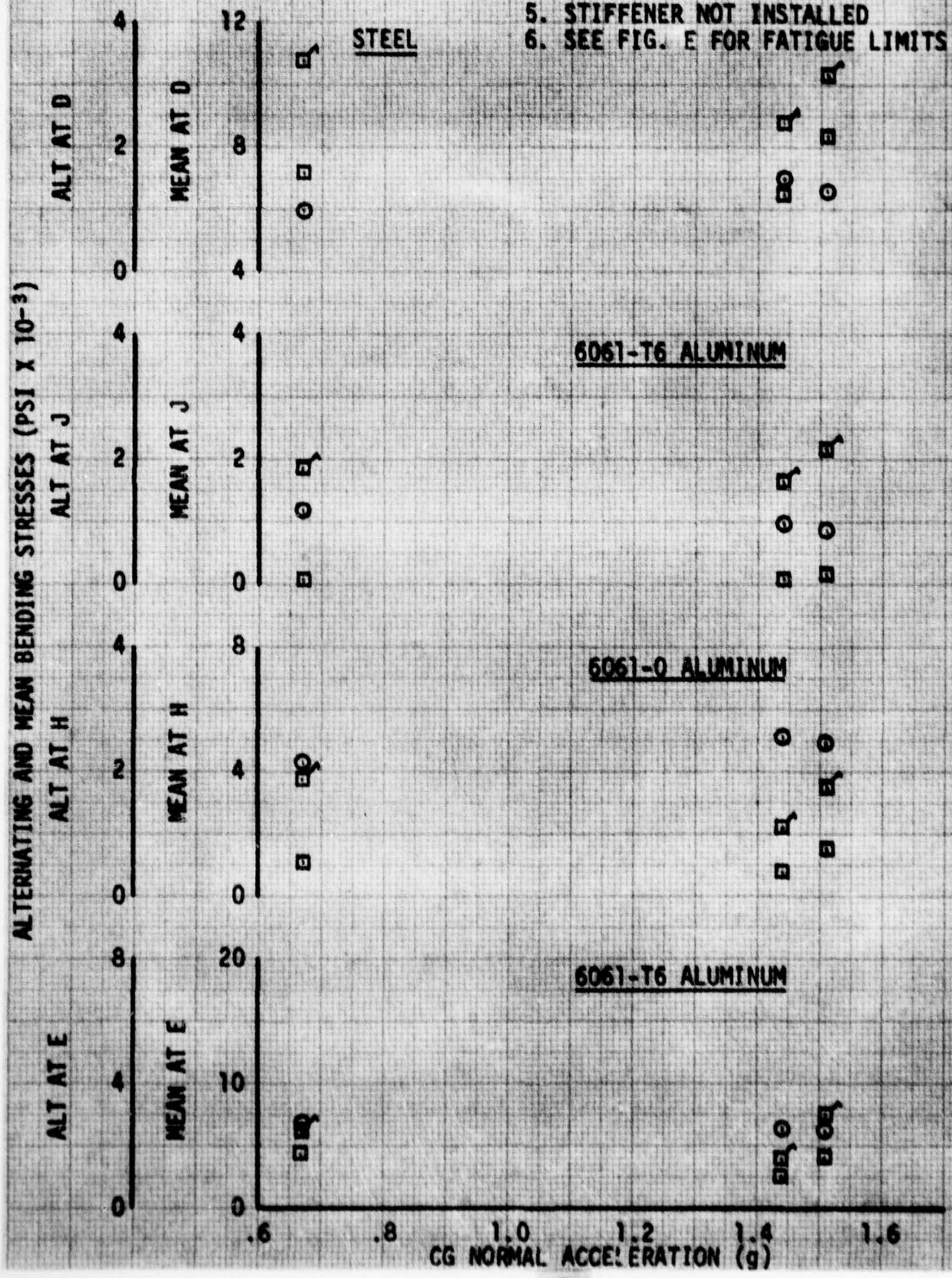


FIGURE 18

BOOM STRESSES IN MANEUVERING FLIGHT

CH-47C/WISS USA S/N 15814

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION (FS)	AVG HD (FT)	AVG OAT (°C)	AVG NR (RPM)	TRIM TRUE A/S (KT)	BOOM POSITION
33980	330.7(MID)	8220	9.0	246	100	DOWN

NOTES:
1. CIRCLES DENOTE MEAN STRESS
2. SQUARES DENOTE ALTERNATING STRESS
3. FLAGS DENOTE X-BENDING (SEE FIG 1, APP B)
4. SPRAY OFF
5. STIFFENER NOT INSTALLED
6. SEE FIG. E FOR FATIGUE LIMITS

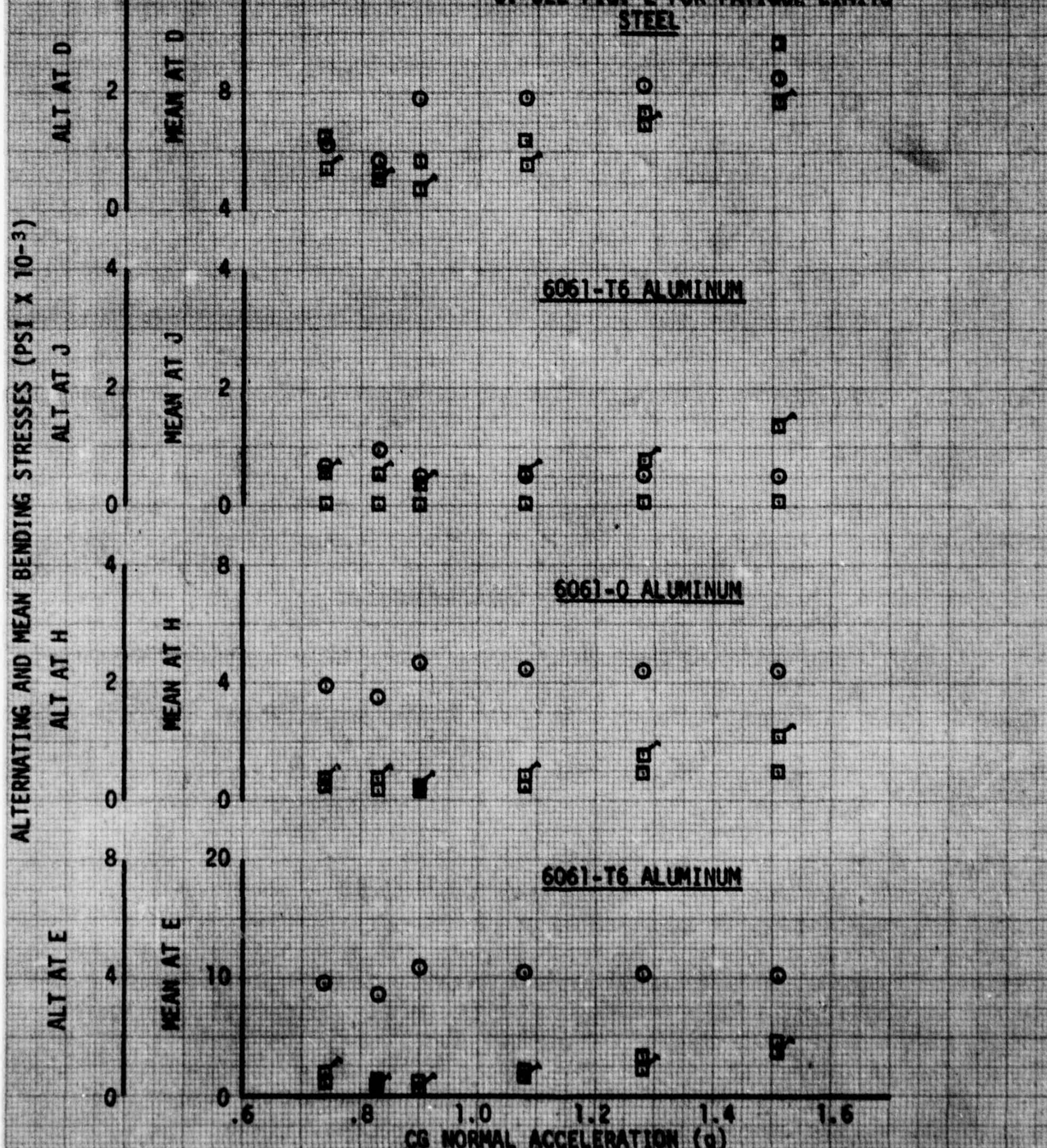


FIGURE 19
BOOM STRESSES IN LEVEL FLIGHT
CH-47C/HISS USA S/N 15814

SYMBOL	AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION (FS)	AVG HD (FT)	AVG OAT (C°)	AVG NR (RPM)	BOOM POSITION
○	39000	331.0(MID)	9900	16.0	235	UP
□	43880	331.1(MID)	9940	13.5	245	UP

NOTES: 1. STIFFENER INSTALLED.
2. SEE FIG. E FOR FATIGUE LIMITS.
3. 6061-T6 ALUMINUM.

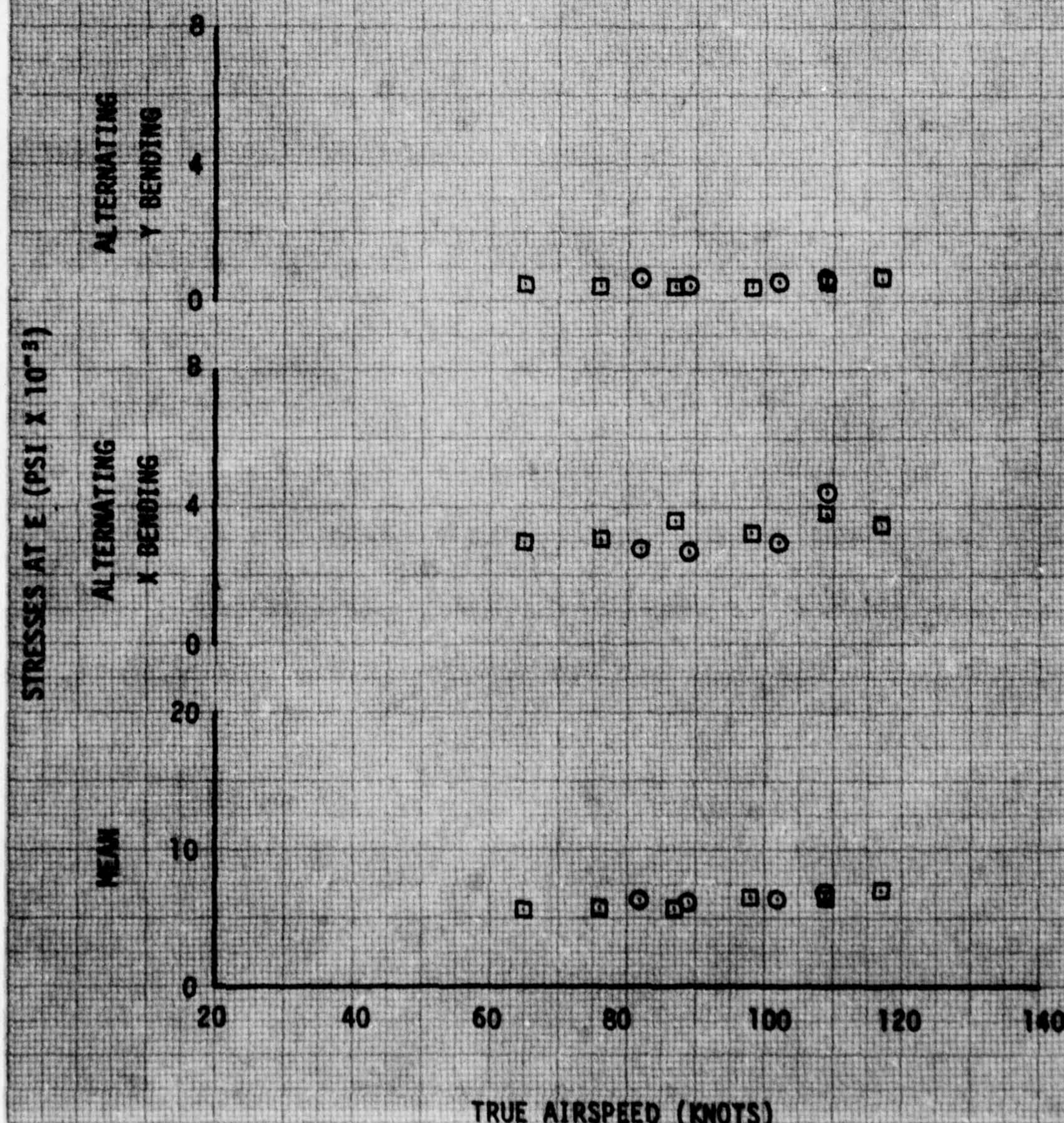


FIGURE 20
BOOM STRESSES IN LEVEL FLIGHT
[illegible] USA S/N [illegible]

SYMBOL	AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION (FS)	AVG HD (FT)	AVG OAT (C°)	AVG NR (RPM)	BOOM POSITION
○	43480	331.1(MID)	9720	21.1	245	DOWN
●	43300	331.1(MID)	9680	20.8	245	DOWN
■	43200	331.1(MID)	9800	13.3	245	DOWN
△	38880	331.0(MID)	9800	17.1	235	DOWN

NOTES:
1. STIFFENER INSTALLED.
2. SHADED SYMBOLS INDICATE SPRAY, 20 GAL/MIN.
3. SEE FIG. E FOR FATIGUE LIMITS.
4. 6061-T6 ALUMINUM.

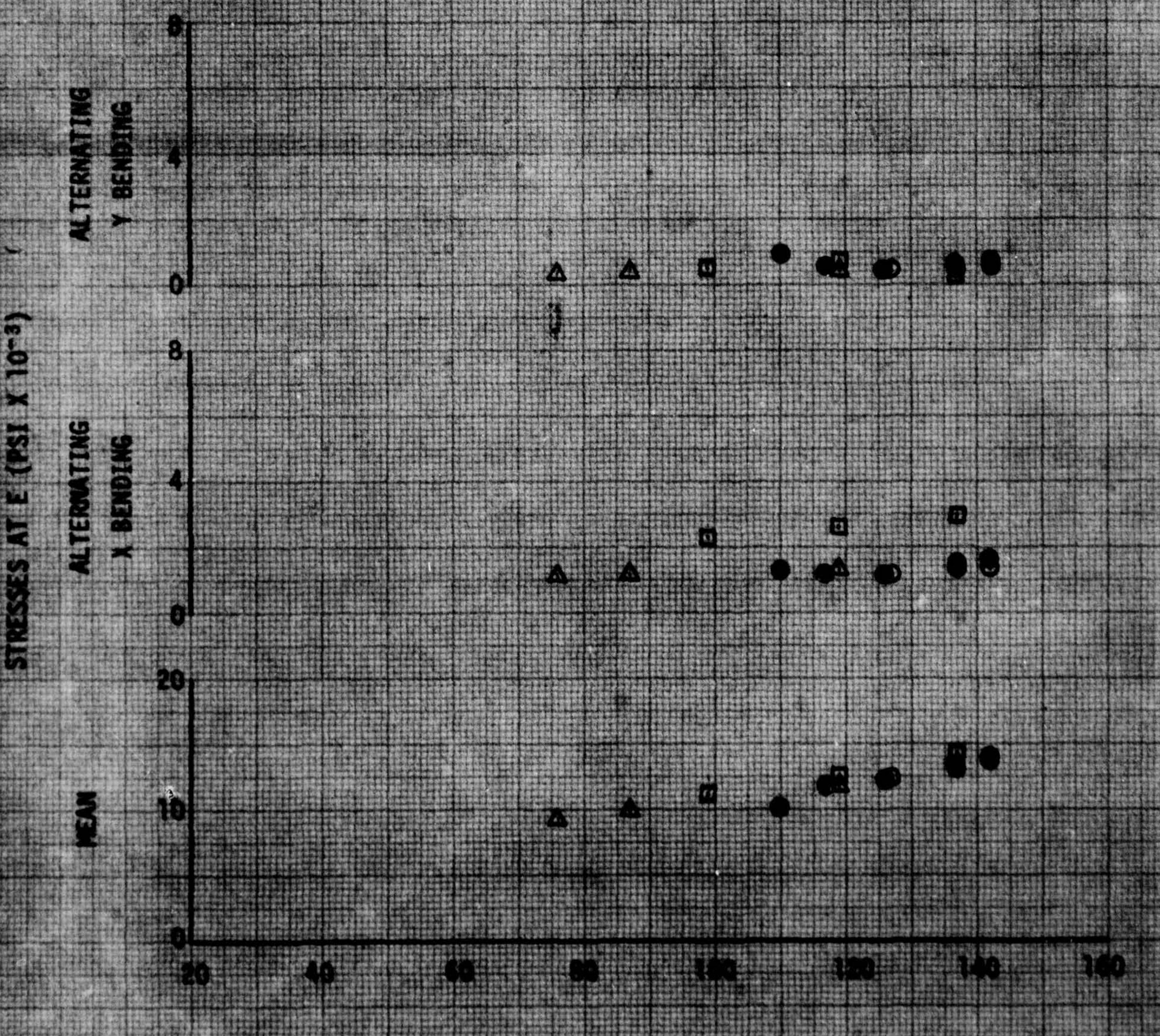


FIGURE 21

BOOM STRESSES IN SIDEWARD FLIGHT

CH-47C/MISS USA S/N 15814

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION (FS)	AVG HD (FT)	AVG OAT (°C)	AVG NR (RPM)	BOOM POSITION
43500	331.0(MID)	4000	25.5	246	UP

NOTES: 1. STIFFENER INSTALLED.
2. SEE FIG. E FOR FATIGUE LIMITS.
3. 6061-T6 ALUMINUM.

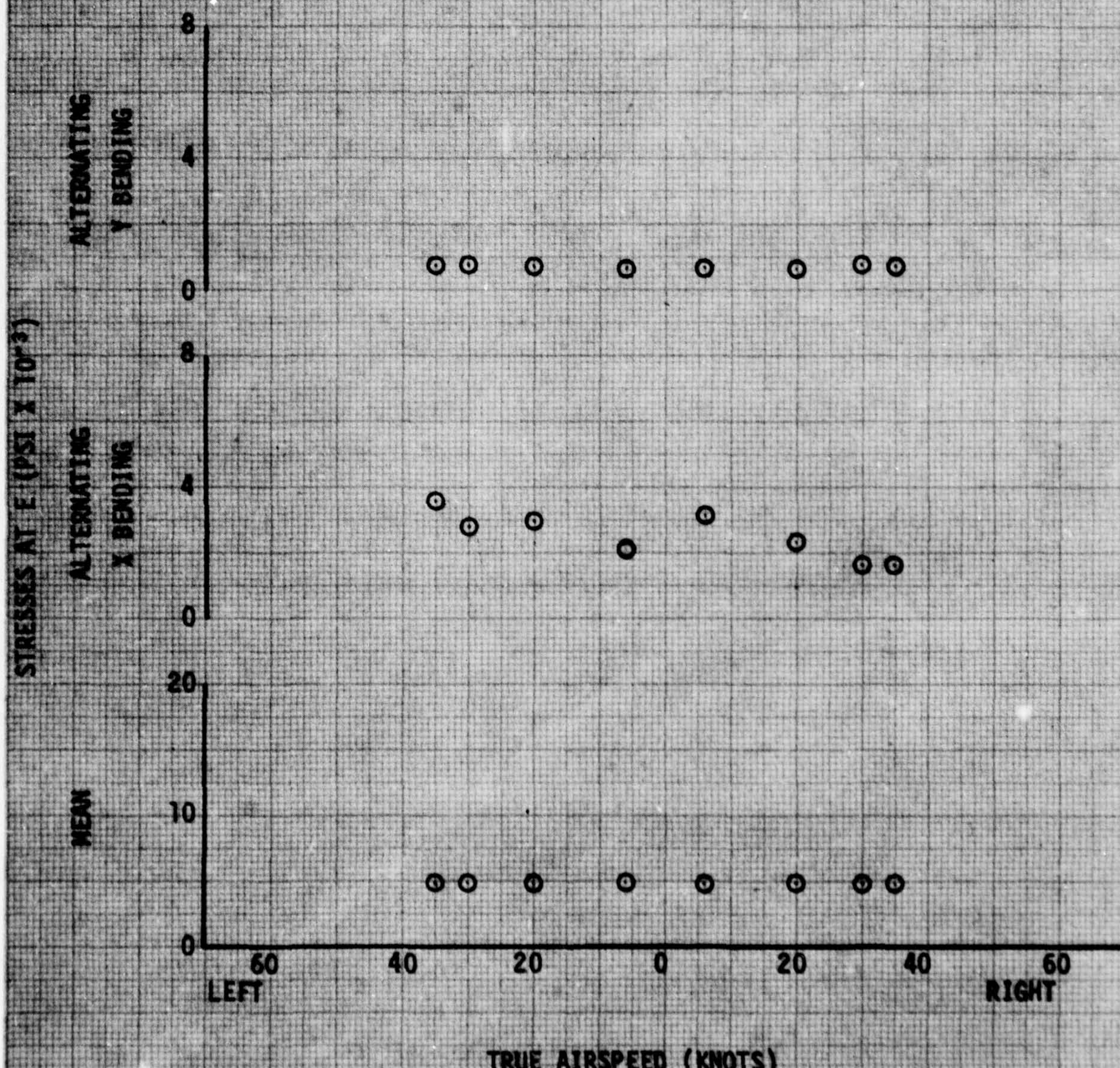
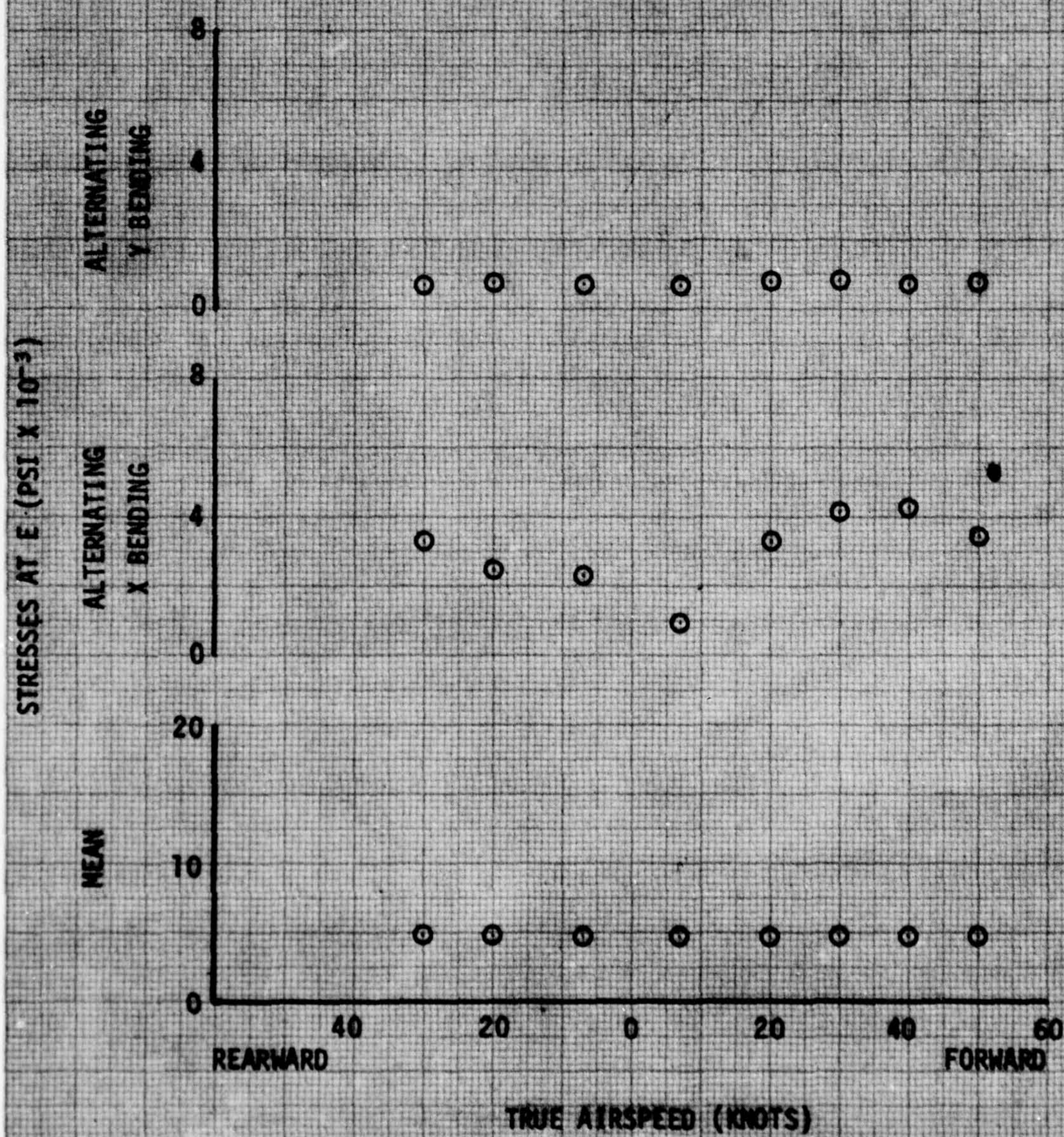


FIGURE 22
BOOM STRESSES IN LOW-SPEED FORWARD AND REARWARD FLIGHT
CH-47C/HISS USA S/N [illegible]

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION (FS)	AVG HD (FT)	AVG OAT (°C)	AVG NR (RPM)	BOOM POSITION
43500	331.0(MID)	4000	25.5	246	UP

NOTES: 1. STIFFENER INSTALLED.
2. SEE FIG. E FOR FATIGUE LIMITS.
3. 6061-T6 ALUMINUM.



APPENDIX D. EQUIPMENT PERFORMANCE REPORT

EQUIPMENT PERFORMANCE REPORT

25 Sept 1975

OFFICE SYMBOL: SAVTE-TA

TO	FROM
COMMANDER ... ARMY A... SYSTEMS COMMAND ATTN: AM... ... ... LOUIS MISSOURI 63166	Commander US Army Aviation Engr Flt Activity ATTN: SAVTE-TA Edwards Air Force Base, CA 93523

	PROJECT NUMBER	3. TEST TITLE
75-04-01	Project 75-04	Modified helicopter icing spray system evaluation

SECTION A - MAJOR ITEM DATA

CH-47C	5. SERIAL NO 15814
1	7. MANUFACTURER Boeing

SECTION B - PART DATA

NOMENCLATURE DESCRIPTION: Lower vertical extension tubes	9. NSN: N/A
MFR PART NO: N/A	11. MANUFACTURER: All American Engineering
QUANTITY: 2	13. NEXT ASSEMBLY: N/A

SECTION C - INCIDENT DATA

14. OBSERVED DURING	15. TEST ENVIRONMENT	16. INCIDENT CLASS	17. ACTION TAKEN
a. OPERATION	Hover, low airspeed boom extended & Retracted water tank, empty and 1100 gallons.	X a. DEFICIENCY	REPLACED
X b. MAINTENANCE		b. SHORTCOMING	REPAIRED
c.		c. SUGGESTED IMPROVEMENT	ADJUSTED
		d. OTHER	DISCONNECTED
			X REMOVED
			NONE

DATE INCIDENT OCCURRED: 25 Sept. 1975

SECTION D - INCIDENT DESCRIPTION

(Deficiencies and Shortcomings are subject to reclassification)

Cracks in weld between upper attaching flange and right-hand tube were discovered during routine inspection following 4th flight. Removal and inspection of left-hand tube revealed similar cracks. Cause appears to be insufficient fusing of weld material and tube. Investigation is continuing. Tubes have been removed and will be replaced.

CORRECTIVE MATERIAL SENT TO

NAME ... OF PREPARER	SIGNATURE
GARY L. BENDER Project Officer	Gary L Bender

SAV Form 1002, 1 Aug 74 — Edition of 20 Oct 71 may be used.

APPENDIX E. SPRAY CLOUD CALIBRATION

1. A listing of symbols and abbreviations used in this appendix is shown below.

Symbol	Definition	Unit
a	Ambient speed of sound	ft/sec
C	Celsius temperature	deg
D	Distance behind CH-47C	ft
G	Thermodynamic function	cm^2/sec
G_O	Constant (60×10^{-8})	cm^2/sec
H_D	Density altitude	ft
H_P	Pressure altitude	ft
$H_{P_{IND}}$	Indicated pressure altitude	ft
$\Delta H_{P_{IC}}$	Altimeter instrument correction	ft
$\Delta H_{P_{PE}}$	Altimeter position error correction	ft
K	Kelvin temperature	deg
LWC_C	Corrected liquid water content	gm/m^3
LWC_D	Decay liquid water content	percent/sec
LWC_P	Programmed liquid water content	gm/m^3
M	Mach number	--
P_{VS}	Saturation vapor pressure for dew point	millibars
P_W	Saturation vapor pressure for static air temperature	millibars
Rh	Relative humidity	percent
T_a	Ambient air temperature	deg

$T_{a_{IND}}$	Indicated ambient air temperature	deg
$\Delta T_{a}IC$	Ambient air temperature instrument correction	deg
T_o	Total temperature	deg
T	Static air temperature	deg
V_{CAL}	Calibrated	kt
V_{IND}	Indicated airspeed	kt
ΔV_{IC}	Airspeed instrument correction	kt
ΔV_{PE}	Airspeed position error	kt
V_T	True airspeed	kt
W_R	HISS water flow rate	gal/min
θ_a	Ambient air temperature ratio	--
ρ	Air density	slug/ft^3
σ	Ambient air density ratio	--

2. Icing severity should be established for each test flight using the following technique. The spray aircraft can establish airspeed, altitude, and static air temperature for the required test condition using calibrated instruments in the CH-47C. Establishing the required LWC is more complicated, since a direct measurement of LWC cannot be made. To obtain the correct LWC, first the forst point should be obtained by utilizing a Cambridge thermoelectric dew-point hygrometer. The frost point should then be converted to a corresponding dew-point condition by a conversion table (table 1) reprinted from the instrument manufacturer's manual. Table 2, published by the Smithsonian Institute, can then be used to determine a saturation vapor pressure (millibars) for the dew-point and static air temperature. Relative humidity can then be computed using the values obtained from table 2 and the following equation:

$$Rh = \frac{P_{VS}}{P_W} \times 100$$

Table 1. Cambridge Thermoelectric Dew Point Hygrometer Conversion Values (Degrees Centigrade).

Frost Point	Dew Point	Frost Point	Dew Point
-0.0	-0.1	-13.0	-14.5
-0.5	-0.7	-13.5	-15.0
-1.0	-1.2	-14.0	-15.6
-1.5	-1.8	-14.5	-16.2
-2.0	-2.3	-15.0	-16.7
-2.5	-2.9	-15.5	-17.3
-3.0	-3.4	-16.0	-17.8
-3.5	-4.0	-16.5	-18.4
-4.0	-4.5	-17.0	-18.9
-4.5	-5.1	-17.5	-19.5
-5.0	-5.6	-18.0	-20.0
-5.5	-6.2	-18.5	-20.6
-6.0	-6.7	-19.0	-21.1
-6.5	-7.3	-19.5	-21.1
-7.0	-7.9	-20.0	-22.2
-7.5	-8.4	-20.5	-22.8
-8.0	-9.0	-21.0	-23.3
-8.5	-9.5	-21.5	-23.9
-9.0	-10.1	-22.0	-24.5
-9.5	-10.6	-22.5	-25.0
-10.0	-11.2	-23.0	-25.6
-10.5	-11.7	-23.5	-26.1
-11.0	-12.3	-24.0	-26.7
-11.5	-12.8	-24.5	-27.2
-12.0	-13.4	-25.0	-27.8
-12.5	-13.9	-25.5	-28.3

Table 2. Saturation Vapor Pressure Over Water. (Millibars)

Temperature °C	0	.1	2	3	4	.5	6	.7	.8	.9
-50	0.06356									
-49	0.07124	0.07044	0.06964	0.06885	0.06807	0.06730	0.06654	0.06578	0.06503	0.06429
-48	0.07975	0.07886	0.07797	0.07710	0.07624	0.07538	0.07453	0.07370	0.07287	0.07205
-47	0.08918	0.08819	0.08722	0.08625	0.08530	0.08435	0.08341	0.08248	0.08156	0.08065
-46	0.09961	0.09852	0.09744	0.09637	0.09531	0.09426	0.09322	0.09220	0.09118	0.09017
-45	0.1111	0.1099	0.1087	0.1075	0.1063	0.1052	0.1041	0.1030	0.1018	0.1007
-44	0.1239	0.1226	0.1213	0.1200	0.1187	0.1174	0.1161	0.1149	0.1136	0.1123
-43	0.1379	0.1364	0.1350	0.1335	0.1321	0.1307	0.1293	0.1279	0.1266	0.1252
-42	0.1534	0.1518	0.1502	0.1486	0.1470	0.1455	0.1440	0.1424	0.1409	0.1394
-41	0.1704	0.1686	0.1669	0.1651	0.1634	0.1617	0.1600	0.1583	0.1567	0.1550
-40	0.1891	0.1872	0.1852	0.1833	0.1815	0.1796	0.1777	0.1759	0.1740	0.1722
-39	0.2097	0.2076	0.2054	0.2033	0.2013	0.1992	0.1971	0.1951	0.1931	0.1911
-38	0.2323	0.2299	0.2276	0.2253	0.2230	0.2207	0.2185	0.2162	0.2140	0.2119
-37	0.2571	0.2545	0.2520	0.2494	0.2469	0.2444	0.2419	0.2395	0.2371	0.2347
-36	0.2842	0.2814	0.2786	0.2758	0.2730	0.2703	0.2676	0.2649	0.2623	0.2597
-35	0.3139	0.3108	0.3077	0.3047	0.3017	0.2987	0.2957	0.2928	0.2899	0.2870
-34	0.3463	0.3429	0.3396	0.3362	0.3330	0.3297	0.3265	0.3233	0.3201	0.3170
-33	0.3818	0.3781	0.3745	0.3708	0.3673	0.3637	0.3602	0.3567	0.3532	0.3497
-32	0.4205	0.4165	0.4125	0.4085	0.4046	0.4007	0.3968	0.3930	0.3893	0.3855
-31	0.4628	0.4584	0.4541	0.4497	0.4454	0.4412	0.4370	0.4328	0.4287	0.4246
-30	0.5088	0.5040	0.4993	0.4946	0.4899	0.4853	0.4807	0.4762	0.4717	0.4672
-29	0.5589	0.5537	0.5485	0.5434	0.5383	0.5333	0.5283	0.5234	0.5185	0.5136
-28	0.6134	0.6077	0.6021	0.5966	0.5911	0.5856	0.5802	0.5748	0.5694	0.5642
-27	0.6727	0.6666	0.6605	0.6544	0.6484	0.6425	0.6366	0.6307	0.6249	0.6191
-26	0.7371	0.7304	0.7238	0.7172	0.7107	0.7042	0.6978	0.6914	0.6851	0.6789
-25	0.8070	0.7997	0.7926	0.7854	0.7783	0.7713	0.7643	0.7574	0.7506	0.7438
-24	0.8827	0.8748	0.8671	0.8593	0.8517	0.8441	0.8366	0.8291	0.8217	0.8143
-23	0.9649	0.9564	0.9479	0.9396	0.9313	0.9230	0.9148	0.9067	0.8986	0.8906
-22	1.0538	1.0446	1.0354	1.0264	1.0173	1.0084	0.9995	0.9908	0.9821	0.9734
-21	1.1500	1.1400	1.1301	1.1203	1.1106	1.1009	1.0913	1.0818	1.0724	1.0631
-20	1.2540	1.2432	1.2325	1.2219	1.2114	1.2010	1.1906	1.1804	1.1702	1.1600
-19	1.3664	1.3548	1.3432	1.3318	1.3204	1.3091	1.2979	1.2868	1.2758	1.2648
-18	1.4877	1.4751	1.4627	1.4503	1.4381	1.4259	1.4138	1.4018	1.3899	1.3781
-17	1.6186	1.6051	1.5916	1.5783	1.5650	1.5519	1.5389	1.5259	1.5131	1.5003
-16	1.7597	1.7451	1.7306	1.7163	1.7020	1.6879	1.6738	1.6599	1.6460	1.6323
-15	1.9118	1.8961	1.8805	1.8650	1.8496	1.8343	1.8191	1.8041	1.7892	1.7744
-14	2.0755	2.0586	2.0418	2.0251	2.0085	1.9921	1.9758	1.9596	1.9435	1.9276
-13	2.2515	2.2333	2.2153	2.1973	2.1795	2.1619	2.1444	2.1270	2.1097	2.0925
-12	2.4409	2.4213	2.4019	2.3826	2.3635	2.3445	2.3256	2.3069	2.2883	2.2698
-11	2.6443	2.6233	2.6024	2.5817	2.5612	2.5408	2.5205	2.5004	2.4804	2.4606
-10	2.8627	2.8402	2.8178	2.7956	2.7735	2.7516	2.7298	2.7082	2.6868	2.6655
- 9	3.0971	3.0729	3.0489	3.0250	3.0013	2.9778	2.9544	2.9313	2.9082	2.8854
- 8	3.3484	3.3225	3.2967	3.2711	3.2457	3.2205	3.1955	3.1706	3.1459	3.1214
- 7	3.6177	3.5899	3.5623	3.5349	3.5077	3.4807	3.4539	3.4272	3.4008	3.3745
- 6	3.9061	3.8764	3.8468	3.8175	3.7883	3.7594	3.7307	3.7021	3.6738	3.6456
- 5	4.2148	4.1830	4.1514	4.1200	4.0888	4.0579	4.0271	3.9966	3.9662	3.9361
- 4	4.5451	4.5111	4.4773	4.4437	4.4103	4.3772	4.3443	4.3116	4.2791	4.2468
- 3	4.8981	4.8617	4.8256	4.7897	4.7541	4.7187	4.6835	4.6486	4.6138	4.5794
- 2	5.2753	5.2364	5.1979	5.1595	5.1214	5.0836	5.0460	5.0087	4.9716	4.9347
- 1	5.6780	5.6365	5.5953	5.5544	5.5138	5.4734	5.4333	5.3934	5.3538	5.3144
- 0	6.1078	6.0636	6.0196	5.9759	5.9325	5.8894	5.8466	5.8040	5.7617	5.7197

3. The percentage of spray cloud evaporation is then computed using the following equation and figure 1.

$$LWC_D = \frac{G(100 - Rh)}{4.5G_O}$$

Where:

G_O is a constant of 60×10^{-8} cm^2/sec

This procedure was recommended by Calspan Inc. following a calibration effort conducted in september 1973 (ref 13, app A). A corresponding increase in water flow rate will adjust the spray cloud to the proper LWC by using:

$$LWC_C = \left(\frac{LWC_D}{100}\right)\left(\frac{D}{1.6889V_T}\right)(LWC_P) + LWC_P$$

Information furnished by the manufacturer of the icing spray system concerning cloud depth at various stand-off distances from a single boom is shown in figure 2. This information and the geometry of the dual boom configuration were used to compute and construct flow rate versus corrected LWC graphs utilizing the conversation of mass principle. The results of these computations are shown in figures 3, 4, and 5. The flow rate established from the above computations and a constant bleed air pressure of 15 pounds per square inch gage (psig) were used to control the spray cloud test environment.

Figure 1. Variation of Thermodynamic Function With Temperature at 1000 Millibars.

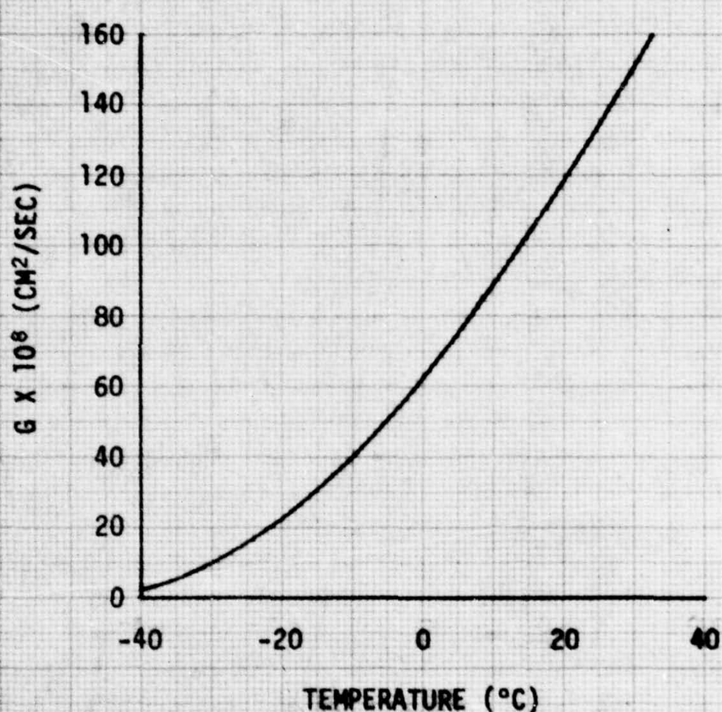


FIGURE 2

VARIATION OF CLOUD DEPTH WITH STAND--OFF DISTANCE

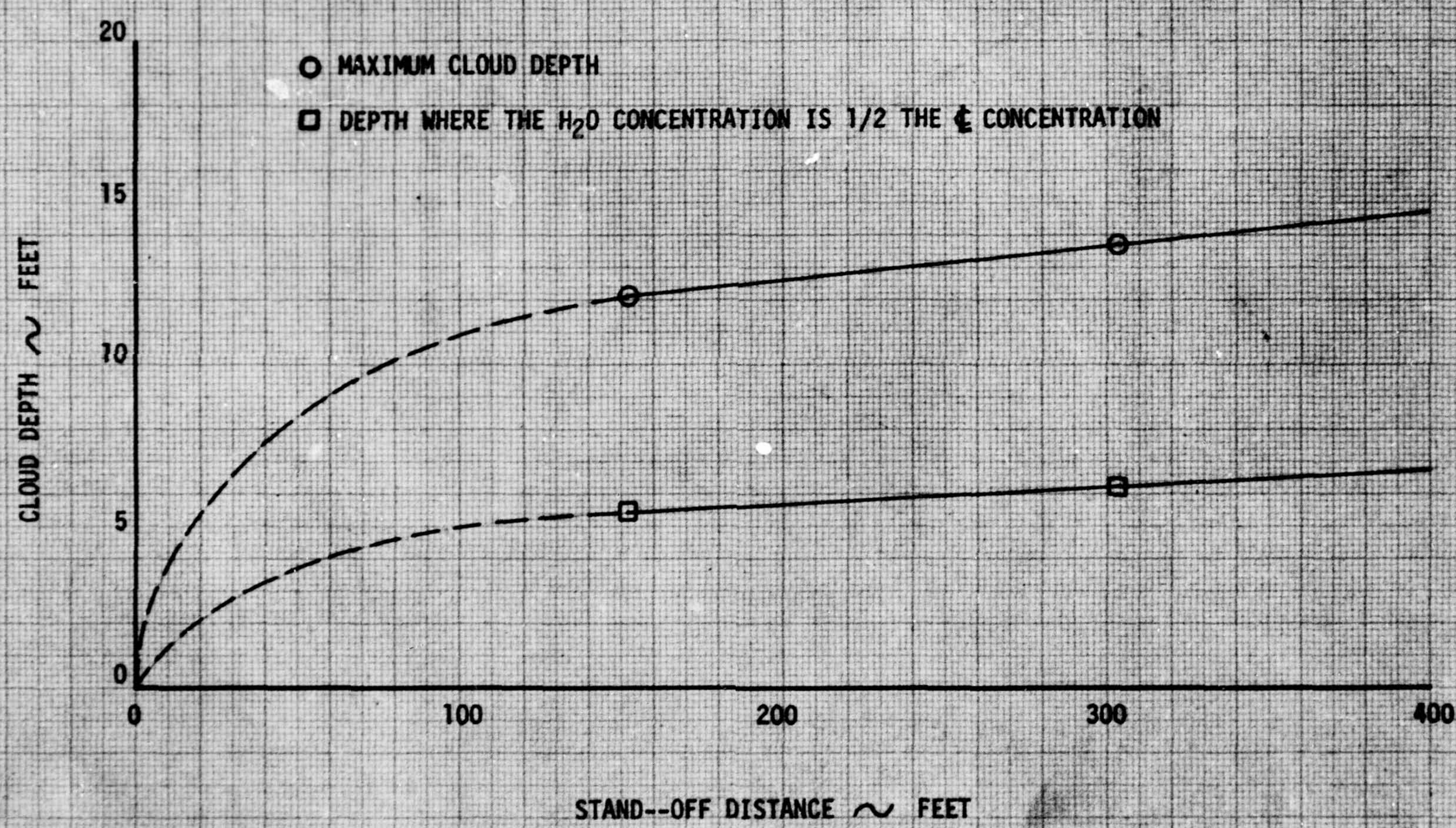


FIGURE 3

WATER FLOW RATE CHART

DUAL BOOM CONFIGURATION

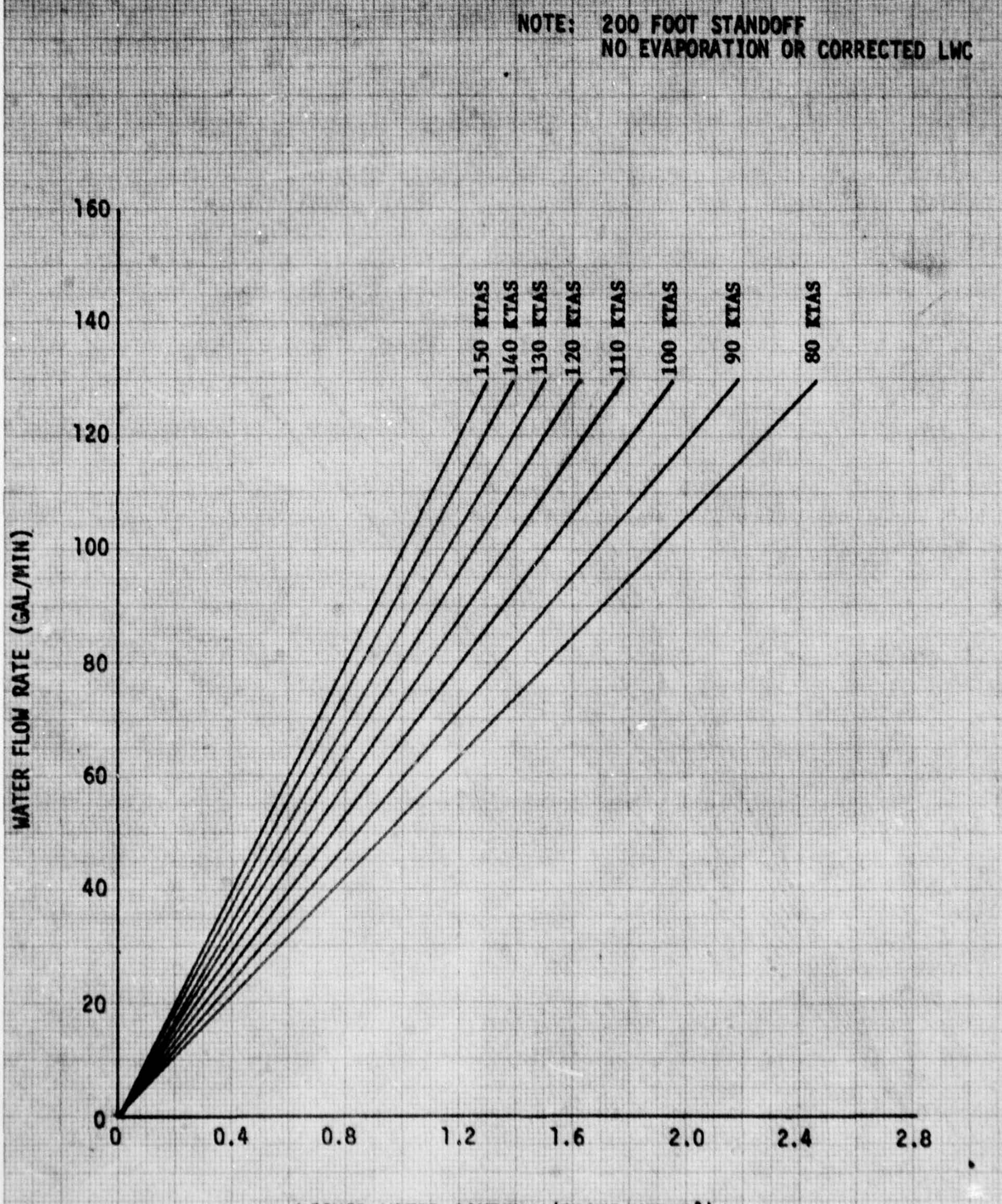


FIGURE 4
WATER FLOW RATE CHART

DUAL BOOM CONFIGURATION

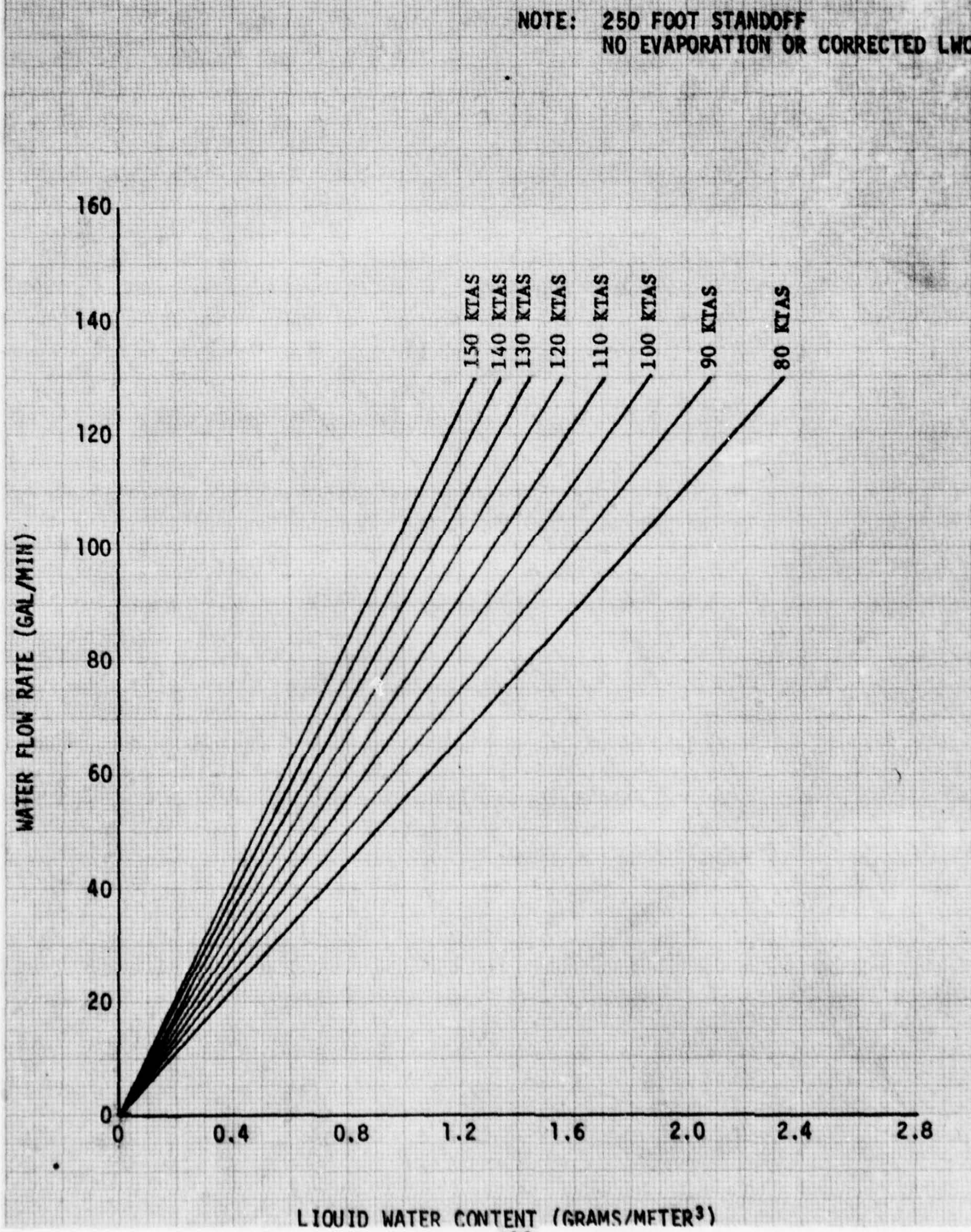
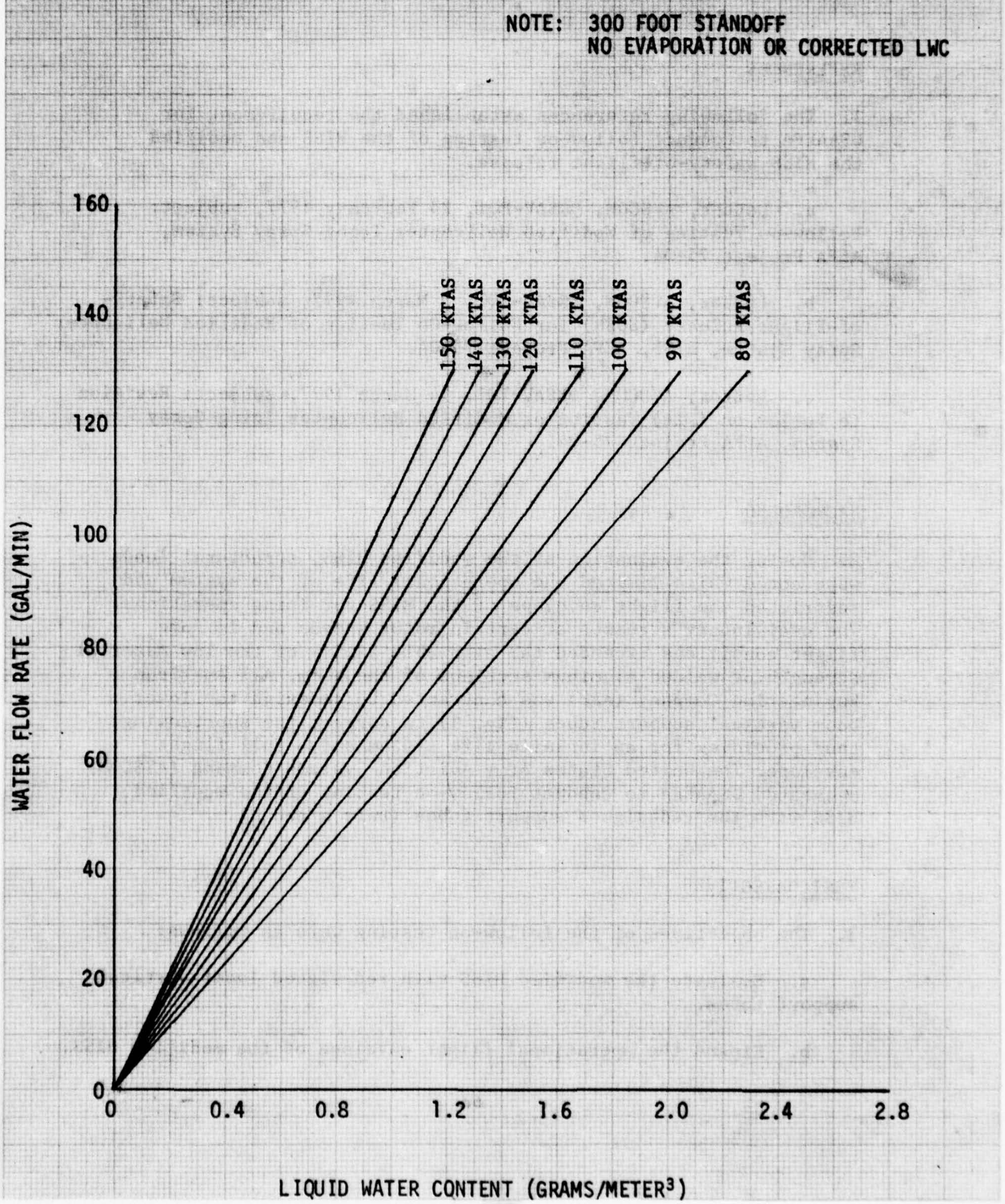


FIGURE 5

WATER FLOW RATE CHART

DUAL BOOM CONFIGURATION



APPENDIX F. FOLLOW-ON TESTING OF THE MODIFIED HELICOPTER ICING SPRAY SYSTEM

REFERENCES

1. The following references established the requirement for USAAEFA to conduct follow-on testing of the HISS and modified the HISS safety-of-flight release.

a. Letter, AVSCOM, DRSAV-EQI, 23 February 1977, subject: Follow-on Testing of Modified Helicopter Icing Spray System, AEFA Project 75-04.

b. Letter, AVSCOM, DRSAV-EQI, 3 March 1977, subject: Safety-of-Flight Release (SOFR) for Follow-On Testing of Modified Helicopter Spray System, HISS, AEFA Project 75-04.

c. Letter, AVSCOM, DRSAV-EQI, 14 March 1977, subject: Revision to Follow on (sic) Testing of Modified Helicopter Icing Spray System, AEFA Project 75-04.

BACKGROUND

2. During the evaluation of the modified HISS, structural loads were noted which limited the operational life of the system and restricted the flight envelope of the HISS for icing operations. The oscillatory stresses at certain rotor speeds and in some flight conditions exceeded the allowable limits of the low material strength of welded aluminum sections of the boom. All American Engineering Company (AAE) was contracted to redesign the lower boom vertical support tubes (fig. 1) to correct the shortcoming, thus providing for an infinite life system and a full flight envelope. The United States Army Aviation Systems Command (AVSCOM) requested USAAEFA to conduct follow-on testing of the modified HISS with the redesigned support tubes (refs a and c).

TEST OBJECTIVES

3. The objectives of the follow-on testing were as follows:

a. Evaluate the modified HISS with redesigned lower vertical support tubes.

b. Expand the operational flight envelope of the modified HISS.

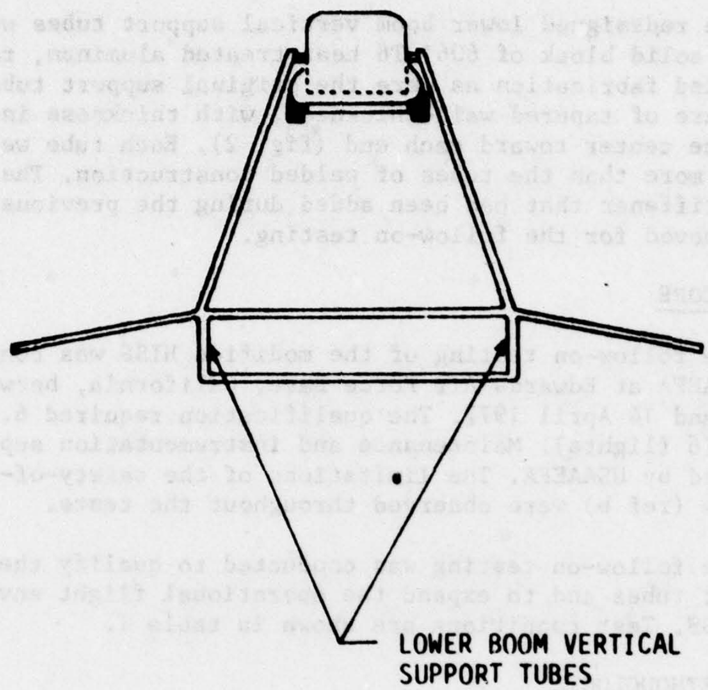


Figure 1. HISS Boom System.

DESCRIPTION

4. The redesigned lower boom vertical support tubes were machined from a solid block of 6061-T6 heat-treated aluminum, rather than of welded fabrication as were the original support tubes. The tubes are of tapered wall-thickness, with thickness increasing from the center toward each end (fig. 2). Each tube weighs 3.75 pounds more than the tubes of welded construction. The lower boom stiffener that had been added during the previous tests was removed for the follow-on testing.

TEST SCOPE

5. The follow-on testing of the modified HISS was conducted by USAAEFA at Edwards Air Force Base, California, between 31 March and 14 April 1977. The qualification required 6.2 flight hours (6 flights). Maintenance and instrumentation support were provided by USAAEFA. The limitations of the safety-of-flight release (ref b) were observed throughout the tests.

6. The follow-on testing was conducted to qualify the redesigned support tubes and to expand the operational flight envelope of the HISS. Test conditions are shown in table 1.

TEST METHODOLOGY

7. The follow-on testing was conducted in accordance with the provisions of AVSCOM Regulation No. 70-11 for envelope expansion. The USAAEFA technical committee reviewed the previous evaluation of the HISS and also the test plan for the follow-on testing.

8. The HISS was instrumented with strain gauges at the locations indicated in figure 3. In addition to the strain gauges, the CH-47C had the test instrumentation listed below installed. Boom stresses were monitored by telemetry during all test flights.

- Rotor speed
- Boom position
- Engineer event
- Center-of-gravity normal acceleration
- Outside air temperature
- Airspeed (ship's system)
- Pressure altitude
- Fuel quantity

9. Detailed methods of test are outlined in the appropriate sections of the Results and Discussion portion of this appendix.

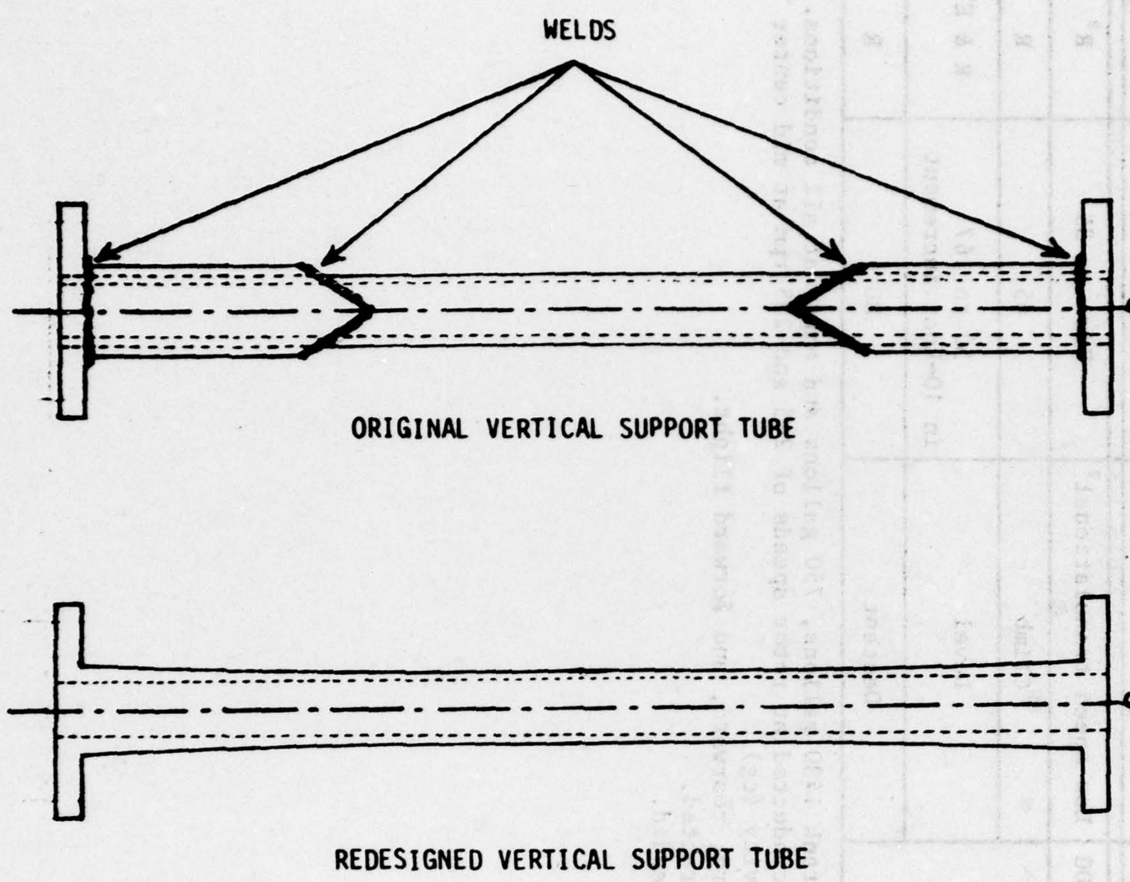


Figure 2. Vertical Support Tubes.

Table 1. Envelope Expansion Test Conditions[1]

Density Altitude (ft)	Flight Condition	True Airspeed (kt)	Boom Position
1800-2700	Low-speed translational[2]	Zero to 35	R[3]
6000	Climb	65	R
	Level	50 to 167 in 10-knot increment	R & E[4]
	Descent	80	R

[1]Water tank 1430 gallons, 750 gallons and empty at all conditions. Tests conducted at rotor speeds of 245 and 235 rpm at mid center of gravity (cg).

[2]Sideward, rearward, and forward flight.

[3]R: Retracted.

[4]E: Extended.

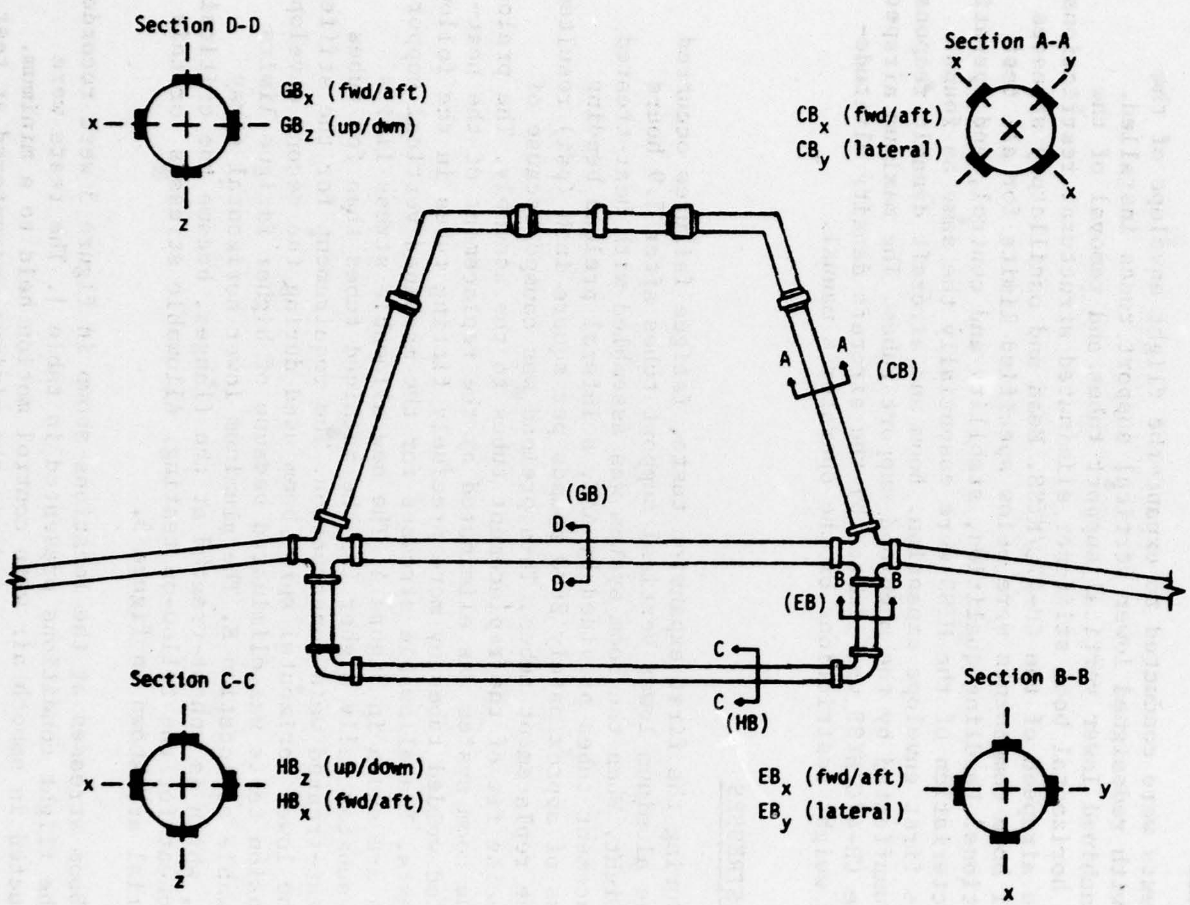


Figure 3. Spray Boom Strain Gauge Locations.

RESULTS AND DISCUSSION

GENERAL

10. Tests were conducted to expand the flight envelope of the HISS with redesigned lower vertical support tubes installed. The machined lower vertical support tubes and removal of the lower horizontal boom stiffener eliminated structural restrictions of the airspeed of the CH-47C/HISS. Mean and oscillatory stresses on all boom components were below specified limits for all test conditions. Handling qualities, stability and control, and operating characteristics of the HISS were essentially the same as found in the first envelope expansion. Boom and aircraft dynamic response were unaffected by the machined support tubes. The maximum airspeed of the CH-47C/HISS was limited by the aircraft density altitude-gross weight restrictions of the operator's manual.

BOOM STRESSES

11. During the first expansion tests, fatigue failures occurred in the aluminum lower vertical support tubes after 5.9 hours of flight. When the boom system was assembled with heat-treated replacement tubes provided by AAE, a lateral preload bending stress of approximately 3600 pounds per square inch (psi) resulted in the replacement tubes. This preload was caused because of imprecise fit of the replacement tubes to the assembly. The preload in the boom system was eliminated by the replacement of the heat-treated welded tubes by more precisely fitting tubes in the follow-on tests. The allowable stresses for the machined vertical support tubes are shown in figure 4. The new allowable stress limits were substantially higher for the machined tubes than for tubes of heat-treated weld construction. The requirement for the stiffener on the lower horizontal spray boom used during the second envelope expansion tests was eliminated because of higher fatigue limits allowable at location E. The aluminum lower horizontal spray boom, which is unheat-treated at the flanges, became the critical component for the follow-on testing. Allowable stresses for this material are shown in figure 5.

12. Boom stresses at the locations shown in figure 3 were recorded at the flight conditions presented in table 1. The tests were conducted in smooth air with control motion held to a minimum. Thus, the stresses presented are the minimum encountered at test conditions. The data are presented as mean bending stress (vector sum of the bending in two axes) and alternating stress (one-half peak-to-peak stress in each axis). Data are presented in figures 6 through 11.

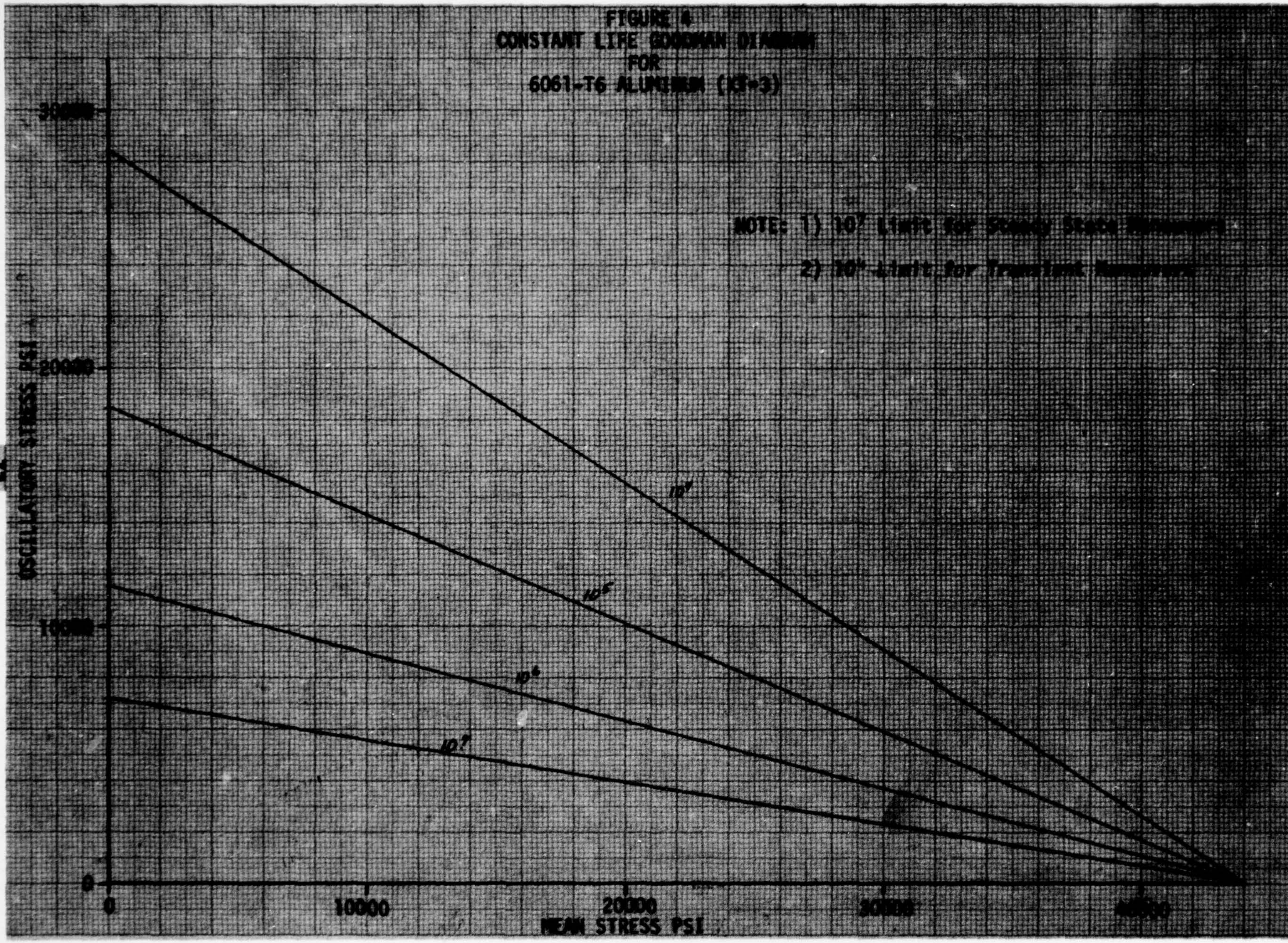


FIGURE 4
CONSTANT LIFE GOODMAN DIAGRAM
FOR
6061-T6 ALUMINUM (KT=3)

FIGURE 5
MODIFIED GOODMAN DIAGRAM

FOR 6061-T6 SOLID LINE
FOR 6061-O DASHED LINE

NOTE: 1) 10^6 Limit for Steady State Maneuvers

2) 10^4 Limit for Transient Maneuvers

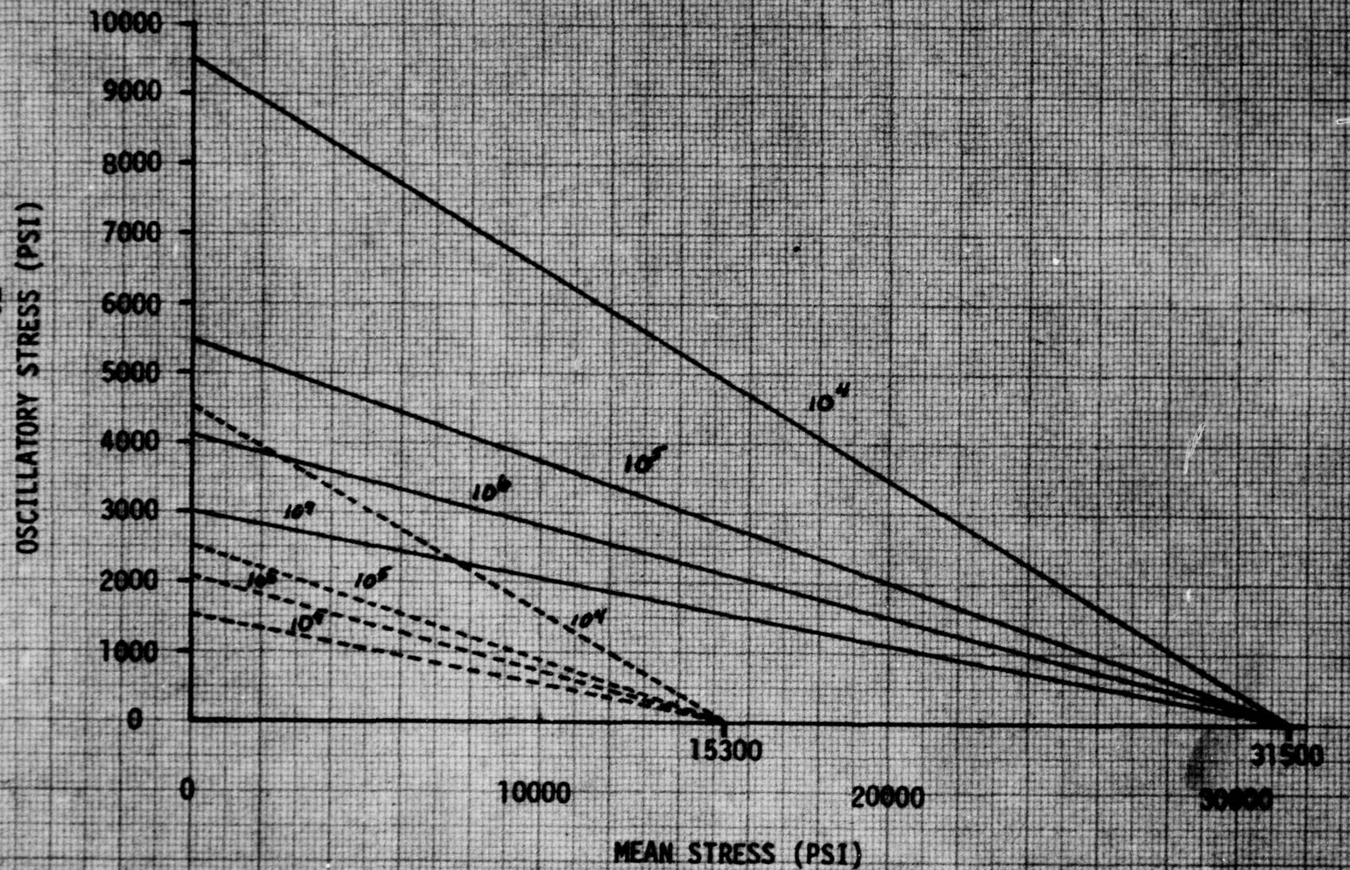


FIGURE 6

BOOM STRESSES AT E IN SIDEWARD FLIGHT

CH-47C/HISS USA S/N 19[illegible]

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	BOOM POSITION
⊙	42480	330.8	1800	6.0	245	UP
⊡	37780	330.5	2300	13.5	235	UP
◆	40640	330.9	2620	15.0	246	UP

NOTES:
1) FLAGS DENOTE X-BENDING (FIG. 3).
2) SHADED SYMBOLS DENOTE WELDED SUPPORT TUBES, 6061-O ALUMINUM.
3) SPRAY OFF.
4) STIFFENER NOT INSTALLED.
5) SEE FIGS 4 AND 5 FOR FATIGUE LIMITS.
6) OPEN SYMBOLS DENOTE 6061-T6 ALUMINUM.

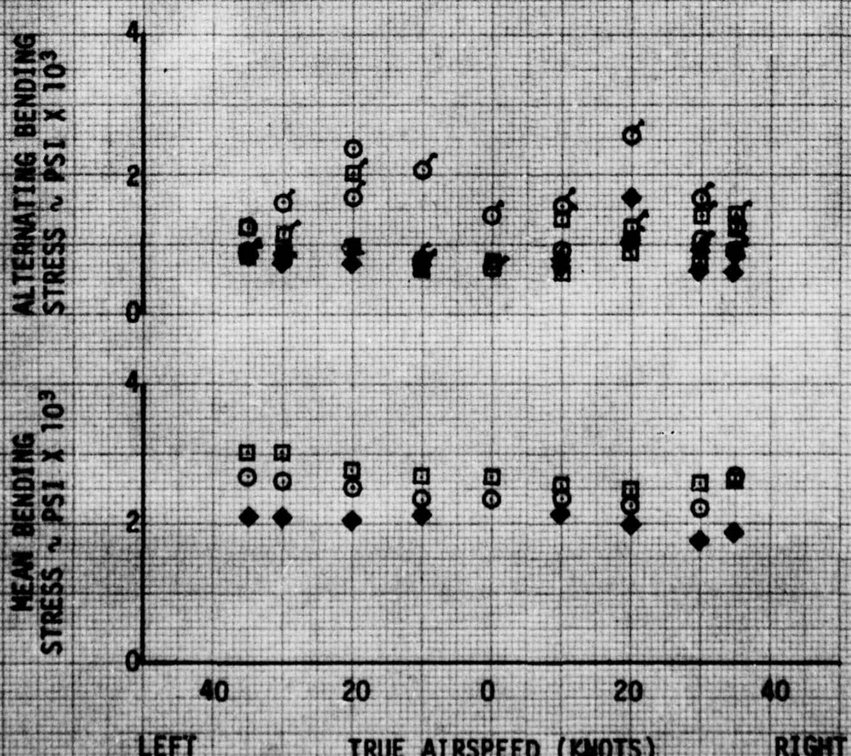


FIGURE 7

BOOM STRESSES AT "H" IN SIDEWARD FLIGHT

CH-47C/HISS USA S/N 16814

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	BOOM POSITION
⊙	42480	330.8	1800	6.0	245	UP
⊡	37780	330.5	2300	13.5	235	UP
◆	40640	330.9	2620	15.0	246	UP

NOTES:
1) FLAGS DENOTE X-BENDING (FIG. 3).
2) SHADED SYMBOLS DENOTE WELDED SUPPORT TUBES.
3) SPRAY OFF.
4) STIFFENER NOT INSTALLED.
5) SEE FIG 5 FOR FATIGUE LIMITS.
6) MATERIAL IS 6061-0 ALUMINUM.

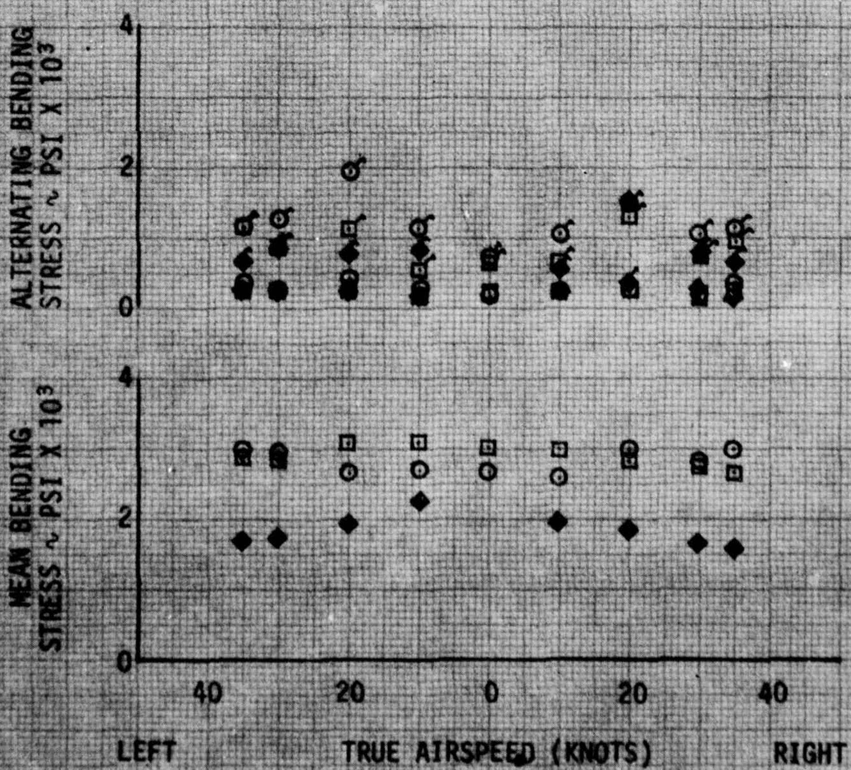


FIGURE 8

BOOM STRESSES AT "E" IN LOW SPEED FORWARD AND REARWARD FLIGHT

CH-47C/HISS USA S/N 15814

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	BOOM POSITION
○	43160	330.6	1800	6.5	245	UP
□	38260	330.3	2700	14.0	235	UP
◇	40760	330.8	2560	15.5	246	UP

NOTES:
1) FLAGS DENOTE X-BENDING (FIG. 3).
2) SHADED SYMBOLS DENOTE WELDED SUPPORT TUBES, 6061-0 ALUMINUM.
3) SPRAY OFF.
4) STIFFENER NOT INSTALLED.
5) SEE FIGS 4 AND 5 FOR FATIGUE LIMITS.
6) OPEN SYMBOLS DENOTE 6061-T6 ALUMINUM.

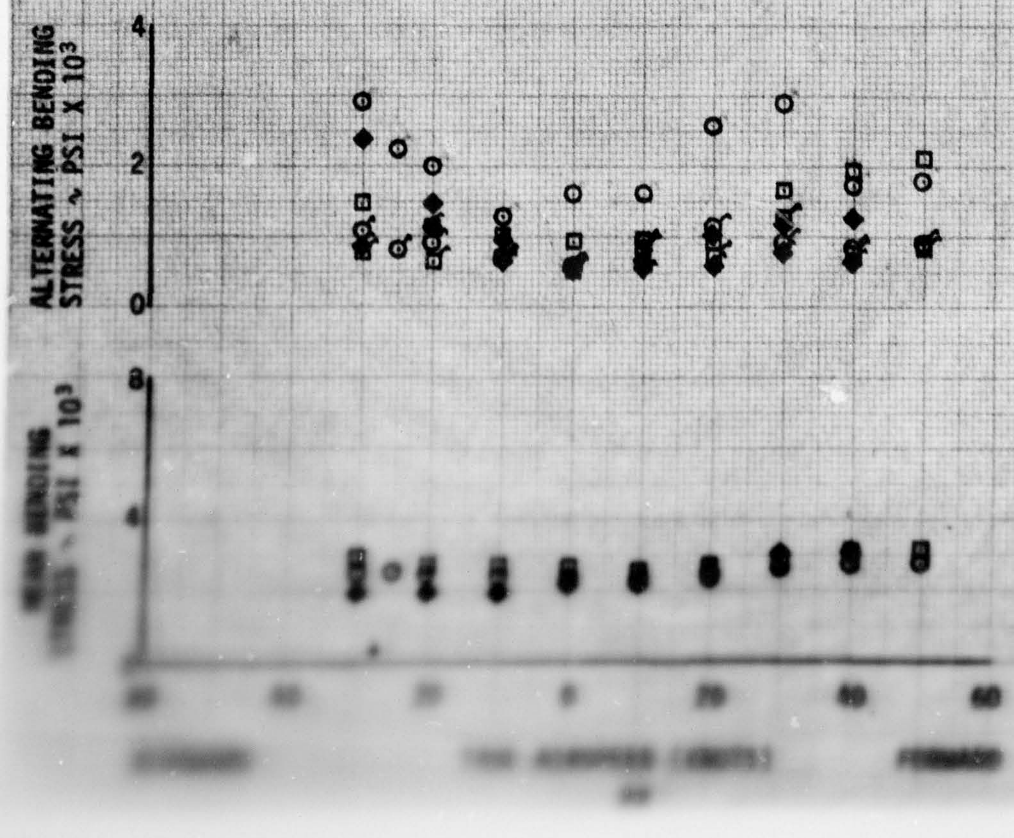


FIGURE 9

BOOM STRESSES AT "H" IN LOW SPEED FORWARD AND REARWARD FLIGHT

CH-47C/HISS USA S/N [illegible]

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	BOOM POSITION
	43160	330.6	1800	6.5	245	UP
	38260	330.3	2700	14.0	235	UP
	40760	330.8	2560	15.5	246	UP

NOTES:
1) FLAGS DENOTE X-BENDING (FIG. 3).
2) SHADED SYMBOLS DENOTE WELDED SUPPORT TUBES.
3) SPRAY OFF.
4) STIFFENER NOT INSTALLED.
5) SEE FIG 5 FOR FATIGUE LIMITS.
6) MATERIAL IS 6061-0 ALUMINUM.

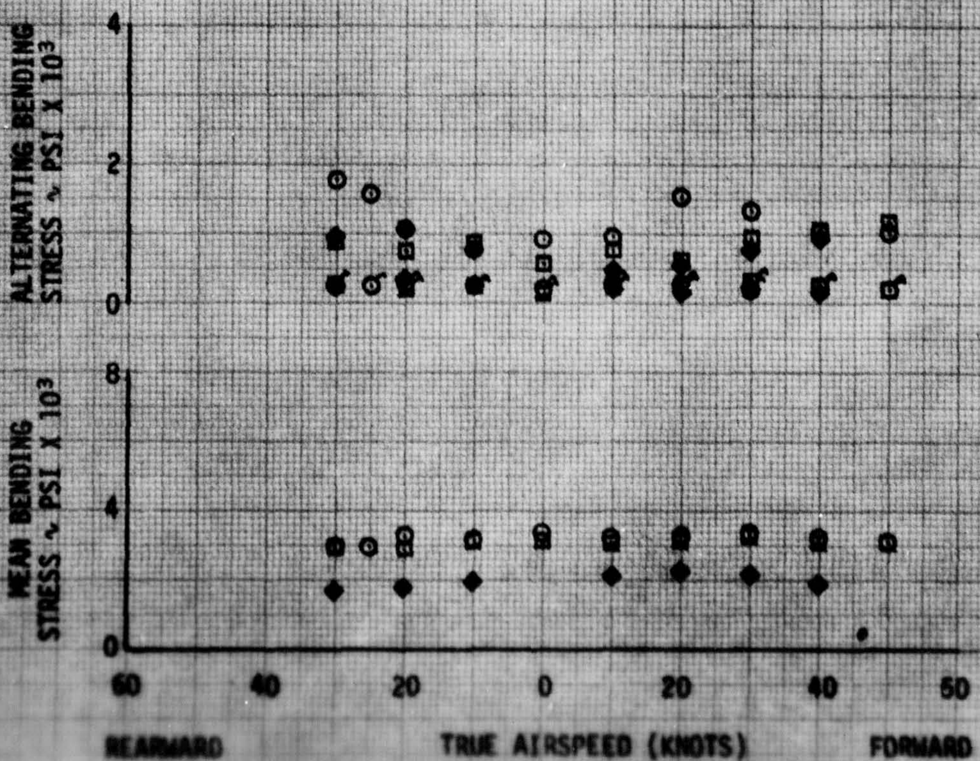


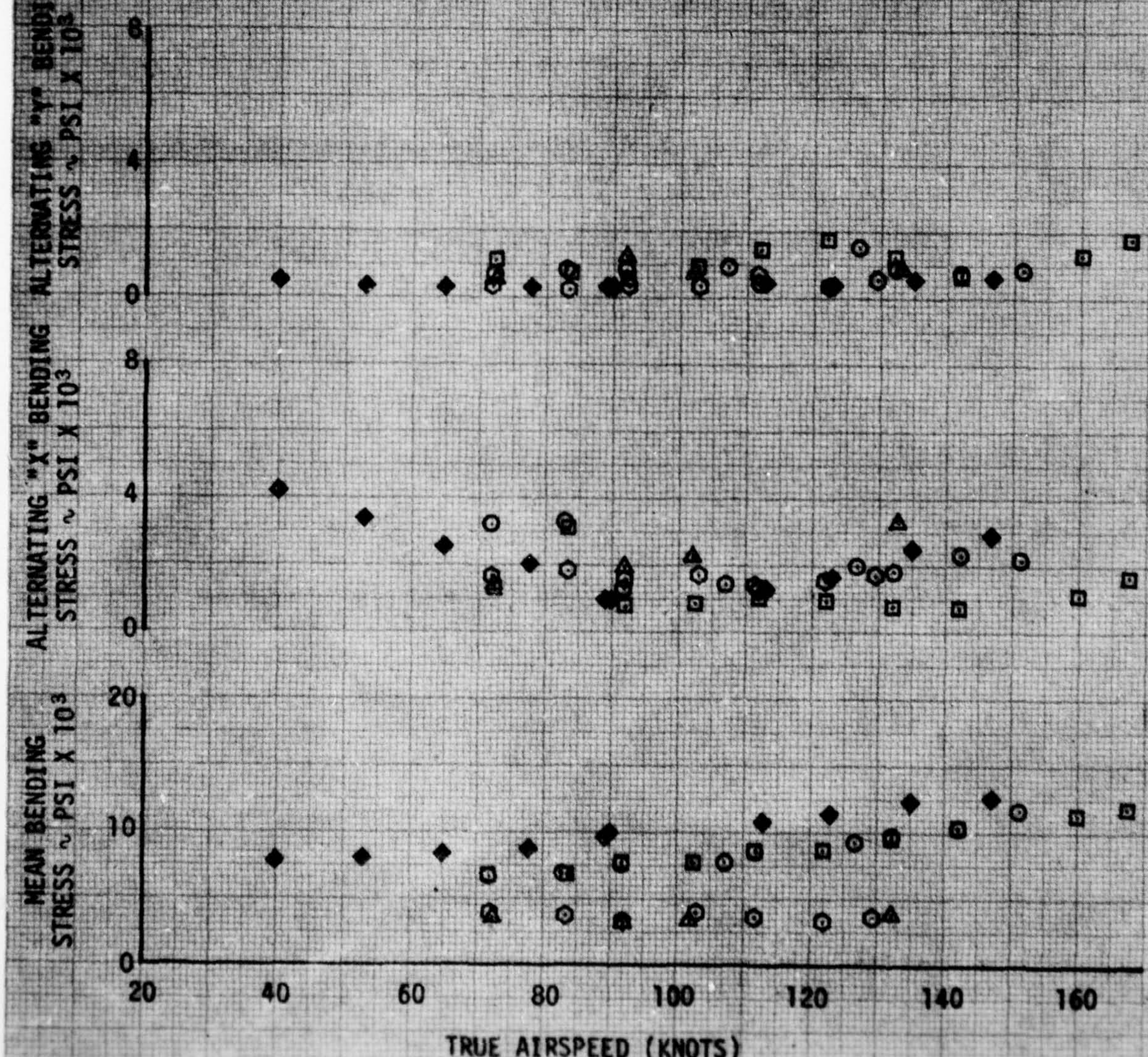
FIGURE 10

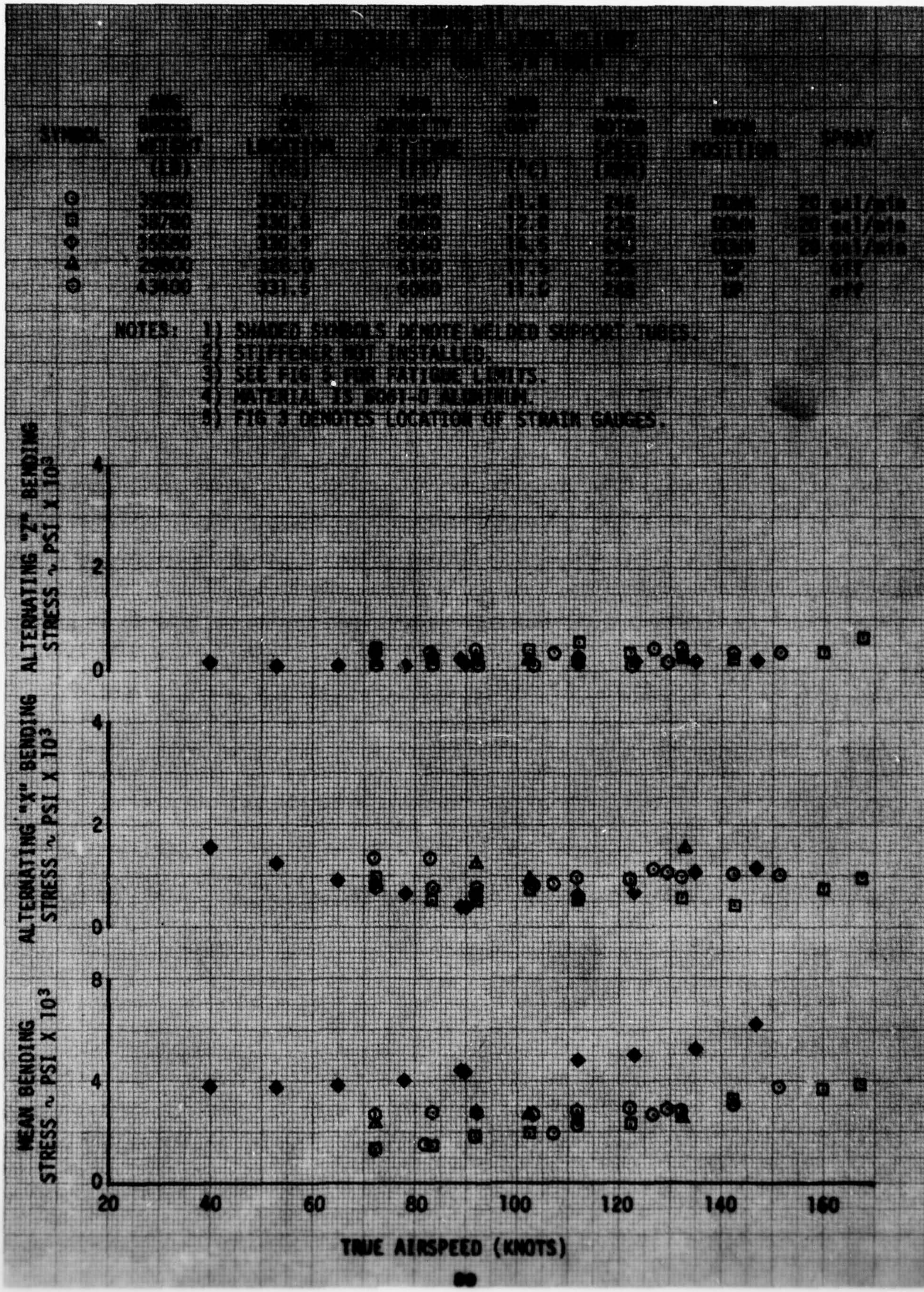
BOOM STRESSES AT "E" IN LEVEL FLIGHT

CH-47C/MISS USA S/N [illegible]

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	BOOM POSITION	SPRAY
○	39280	330.7	5940	11.5	245	DOWN	20 gal/min
□	38780	330.8	6060	12.0	235	DOWN	20 gal/min
◇	35580	330.9	8640	14.5	245	DOWN	20 gal/min
△	29800	328.0	6160	11.5	235	UP	off
⬡	43400	331.5	6060	11.0	245	UP	off

NOTES:
1) SHADED SYMBOLS DENOTE WELDED SUPPORT TUBES.
2) STIFFENER NOT INSTALLED.
3) SEE FIGS 4 AND 5 FOR FATIGUE LIMITS.
4) MATERIAL IS 6061-T6 ALUMINUM.
5) FIG. 3 DENOTES LOCATION OF STRAIN GAUGES.




SYMBOL
LOCATION
POSITION
SPRAY
NOTES: 1) SHADED SYMBOLS DENOTE WELDED SUPPORT TUBES.
2) STIFFENER NOT INSTALLED.
3) SEE FIG 5 FOR FATIGUE LIMITS.
5) FIG 3 DENOTES LOCATION OF STRAIN GAUGES.
ALTERNATING "Z" BENDING STRESS ~ PSI X 10³
ALTERNATING "X" BENDING STRESS ~ PSI X 10³
MEAN BENDING STRESS ~ PSI X 10³
0
2
4
8
20
40
60
80
100
120
140
160
TRUE AIRSPEED (KNOTS)

13. The alternating and mean stresses in the steel components of the HISS were unaffected by the replacement of the vertical support tubes and removal of the stiffener. Stresses in aluminum members of the boom were changed by the replacement of the vertical tubes. The differences are attributed to a reduction in preload (para 11) and to the different stiffness and weight of the new tubes. Stresses in the aluminum components while spraying and with the boom retracted were below allowable limits. Stresses in all boom components were below the current limits at all conditions tested. The CH-47C flight envelope should not be restricted as a result of HISS installation except for minimum extension/retraction airspeed. This airspeed should be limited to 40 knots indicated airspeed (KIAS).

CONCLUSIONS

14. The modified HISS with machined lower vertical support tubes installed and no stiffener on the lower horizontal spray tube, is airworthy within the CH-47C flight envelope with the boom up, down, and while spraying. The boom should not be extended or retracted above 40 KIAS.

RECOMMENDATIONS

15. The modified HISS should be restricted to the current CH-47C flight envelope with the additional restriction that the boom be extended and retracted at or below 40 KIAS.